RESEARCH PAPER

MANAGEMENT OF CHRONIC VENOUS INSUFFICIENCY: SURGICAL AND MINIMALLY INVASIVE APPROACHES

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ABSTRACT

Chronic venous insufficiency (CVI) is a prevalent vascular disorder resulting from venous hypertension caused by valvular incompetence, venous obstruction, or dysfunction of the calf muscle pump. Clinical manifestations range from lower limb discomfort, edema, and varicose veins to skin changes and venous ulceration. Over the past two decades, treatment strategies for CVI have evolved substantially, shifting from conventional open surgery toward minimally invasive endovenous interventions. Traditional surgical procedures such as high ligation and vein stripping remain effective but are increasingly being replaced by endovenous laser ablation (EVLA), radiofrequency ablation (RFA), mechanochemical ablation (MOCA), cyanoacrylate closure (CAC), and ultrasound-guided foam sclerotherapy (UGFS). These minimally invasive techniques offer reduced postoperative pain, faster recovery, improved cosmetic outcomes, and high long-term vein closure rates. Current clinical guidelines recommend endovenous ablation as the preferred treatment for symptomatic saphenous vein reflux when feasible. This narrative review summarizes the pathophysiology of CVI, discusses surgical and minimally invasive treatment modalities, evaluates clinical outcomes, and highlights recent advances and future directions in management.

Keywords: Chronic venous insufficiency, varicose veins, endovenous laser ablation, radiofrequency ablation, cyanoacrylate closure, mechanochemical ablation, venous reflux, minimally invasive surgery.

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INTRODUCTION

Chronic Venous Insufficiency (CVI) is a common vascular disorder characterized by impaired venous return from the lower extremities due to venous valvular incompetence, venous obstruction, or dysfunction of the calf muscle pump. The condition results in sustained venous hypertension, leading to a spectrum of clinical manifestations ranging from mild symptoms such as leg heaviness, pain, and edema to severe complications including skin changes, lipodermatosclerosis, and venous ulceration. CVI represents a significant public health concern because of its high prevalence, chronic nature, impact on quality of life, and substantial healthcare costs associated with long-term management and treatment of complications.[1]

The prevalence of CVI increases with advancing age and is influenced by several risk factors, including female sex, obesity, prolonged standing, sedentary lifestyle, pregnancy, family history, and previous episodes of deep vein thrombosis.[2] Epidemiological studies indicate that chronic venous disorders affect a considerable proportion of the adult population worldwide, with varying degrees of severity.[3] The disease not only imposes physical discomfort but also contributes to psychological distress, reduced work productivity, and impaired social functioning.[4]

The pathophysiology of CVI is complex and involves venous reflux, venous obstruction, or a combination of both. Persistent venous hypertension initiates inflammatory changes within the venous wall and surrounding tissues, resulting in endothelial dysfunction, leukocyte activation, and microcirculatory impairment. These pathological processes contribute to edema, tissue fibrosis, skin pigmentation, and eventually ulcer formation.[5] Understanding these mechanisms has facilitated the development of targeted therapeutic interventions aimed at correcting underlying venous abnormalities and preventing disease progression.

Traditionally, management of CVI relied heavily on conservative measures such as compression therapy, limb elevation, exercise, and lifestyle

modifications. While these approaches remain fundamental components of treatment, they often provide symptomatic relief rather than definitive correction of venous reflux.[6] Surgical interventions, particularly high ligation and stripping of the great saphenous vein, have long been considered the standard treatment for symptomatic varicose veins and advanced venous insufficiency.[7] However, conventional surgery is associated with postoperative pain, bruising, longer recovery periods, and potential recurrence.

Over the past two decades, significant technological advancements have transformed the treatment landscape of CVI. Minimally invasive endovenous procedures, including endovenous laser ablation (EVLA), radiofrequency ablation (RFA), mechanochemical ablation, and ultrasound-guided foam sclerotherapy, have emerged as effective alternatives to traditional surgery. These techniques offer several advantages, including reduced procedural morbidity, shorter recovery times, improved cosmetic outcomes, and high rates of vein closure.[8,9] Contemporary clinical guidelines increasingly recommend endovenous thermal ablation as the preferred first-line intervention for many patients with superficial venous reflux.[10]

Given the growing adoption of minimally invasive technologies and ongoing refinement of surgical techniques, a comprehensive evaluation of current management strategies for CVI is essential. This narrative review aims to examine the principles, indications, outcomes, advantages, and limitations of both surgical and minimally invasive approaches in the treatment of chronic venous insufficiency, while highlighting recent advances and future directions in this rapidly evolving field.

METHODOLOGY

This narrative review was conducted through a comprehensive literature search of PubMed, Scopus, Web of Science, Google Scholar, and major vascular surgery society guidelines. Keywords included “chronic venous insufficiency,” “varicose veins,” “endovenous laser ablation,” “radiofrequency ablation,” “mechanochemical ablation,” “cyanoacrylate closure,” “vein stripping,” and “venous outcomes.” Priority was given to systematic reviews, meta-analyses, randomized controlled trials, and recent guideline statements published between 2015 and 2025. Relevant studies evaluating treatment efficacy, recurrence rates, complications, quality-of-life outcomes, and emerging technologies were included.

LITERATURE REVIEW

Pathophysiology of Chronic Venous Insufficiency

The venous circulation of the lower extremities relies on the coordinated function of competent venous valves, structurally intact venous walls, and an effective calf muscle pump mechanism to ensure unidirectional blood flow toward the heart. Any disruption in these components can result in venous reflux, venous obstruction, or both, leading to the development of chronic venous insufficiency (CVI).[11] Venous valve incompetence is the most common underlying abnormality and permits retrograde blood flow during ambulation, thereby increasing venous pressure within the superficial and deep venous systems.[12]

Sustained ambulatory venous hypertension initiates a cascade of pathological changes affecting both the venous wall and surrounding tissues. Elevated venous pressure promotes endothelial activation and dysfunction, which subsequently triggers leukocyte adhesion, migration, and inflammatory mediator release.[13] Chronic inflammation contributes to venous wall remodeling, valve degeneration, and progressive worsening of venous reflux. Additionally, increased capillary permeability results in extravasation of plasma proteins and erythrocytes into the interstitial space, causing edema and tissue hypoxia.[14]

Over time, persistent venous hypertension leads to microcirculatory dysfunction characterized by fibrin cuff formation, impaired oxygen diffusion, and chronic inflammatory changes within the skin and subcutaneous tissues. These processes are responsible for the characteristic clinical manifestations of advanced CVI, including hyperpigmentation, lipodermatosclerosis, atrophie blanche, and venous ulceration.[15] The development of venous ulcers represents the final stage of a complex pathophysiological process involving inflammation, tissue ischemia, and impaired wound healing.

The Clinical-Etiological-Anatomical-Pathophysiological (CEAP) classification system remains the internationally accepted framework for categorizing chronic venous disorders and facilitating standardized assessment.[16] Clinical manifestations range from telangiectasias and reticular veins (C1) to varicose veins (C2), edema (C3), skin changes such as pigmentation and eczema (C4), healed venous ulcers (C5), and active venous ulceration (C6). The CEAP system provides valuable information regarding disease severity, anatomical involvement, and underlying pathophysiological mechanisms, thereby guiding treatment selection and prognostic evaluation.[17]

Diagnosis and Preoperative Evaluation

Duplex Ultrasonography

Duplex ultrasonography is widely regarded as the gold-standard diagnostic modality for the evaluation of chronic venous insufficiency. This non-invasive imaging technique combines real-time B-mode imaging with Doppler flow assessment, enabling detailed visualization of venous anatomy and hemodynamics.[18] Duplex ultrasound accurately identifies venous reflux, venous obstruction, perforator incompetence, and deep venous

pathology while providing essential information for treatment planning.

The examination allows precise measurement of reflux duration and localization of incompetent venous segments within the superficial, deep, and perforator venous systems. Mapping of venous anatomy before intervention is critical for selecting appropriate surgical or endovenous treatment strategies and optimizing procedural outcomes. Current international vascular guidelines strongly endorse duplex ultrasonography as the primary investigation for patients with suspected chronic venous disease.[19]

Clinical Assessment

Comprehensive clinical evaluation remains fundamental in the management of CVI. Assessment includes detailed history-taking, physical examination, CEAP classification, and quantification of disease severity using validated scoring systems. The Venous Clinical Severity Score (VCSS) is commonly employed to monitor disease progression and evaluate treatment outcomes by assessing pain, edema, skin changes, ulcer characteristics, and compression therapy compliance.[20]

In addition to objective clinical measurements, patient-reported outcome measures play an increasingly important role in modern venous practice. Quality-of-life instruments such as the VEINES-QOL/Sym questionnaire provide valuable insights into symptom burden, functional limitations, and psychosocial impact, thereby facilitating patient-centered treatment decisions and long-term outcome assessment.

Surgical Management of Varicose Veins

High Ligation and Stripping

For several decades, high ligation and stripping (HL/S) represented the standard surgical treatment for great saphenous vein incompetence and symptomatic varicose veins. The procedure involves surgical ligation of the saphenofemoral junction, followed by removal of the incompetent great saphenous vein through a stripping technique. The primary objective is the elimination of pathological venous reflux and restoration of normal venous hemodynamics.

Numerous long-term studies have demonstrated that HL/S provides effective reflux control and durable anatomical success, particularly in patients with extensive superficial venous disease. The procedure has historically served as the benchmark against which newer minimally invasive therapies have been evaluated.

Advantages

- Proven long-term efficacy with established outcome data spanning several decades.
- Effective elimination of saphenous vein reflux and associated venous hypertension.
- Suitable for patients with extensive varicose veins and complex venous anatomy.
- Lower rates of persistent truncal reflux following technically successful procedures.

Limitations

- Requirement for general, spinal, or regional anesthesia.
- Increased postoperative pain and discomfort compared with endovenous techniques.
- Higher incidence of bruising, hematoma formation, and wound-related complications.
- Prolonged recovery period with delayed return to normal activities.
- Risk of sensory nerve injury, particularly involving the saphenous nerve.

Although long-term anatomical outcomes remain favorable, contemporary evidence suggests that patient satisfaction, postoperative recovery, and early quality-of-life improvements are generally superior following minimally invasive endovenous procedures. Consequently, while HL/S continues to have a role in selected clinical scenarios, it has largely been supplanted by endovenous interventions as first-line treatment in many vascular centers worldwide.

Ambulatory Phlebectomy

Ambulatory phlebectomy is a minimally invasive surgical technique designed to remove superficial varicose veins through multiple tiny skin punctures or micro-incisions. The procedure is commonly performed under local anesthesia and is particularly effective for treating tributary varicosities that persist after correction of underlying truncal venous reflux.[21] Since its introduction, ambulatory phlebectomy has become an integral component of comprehensive varicose vein management due to its excellent clinical and cosmetic outcomes.

The procedure is frequently combined with endovenous ablation techniques such as endovenous laser ablation (EVLA) or radiofrequency ablation (RFA) to address both the source of reflux and visible varicosities during the same treatment session.[22] Removal of dilated superficial veins not only improves aesthetic appearance but also contributes to symptom relief by reducing venous pooling, local inflammation, and venous hypertension. Patients commonly experience improvement in pain, heaviness, swelling, and cosmetic concerns following treatment.

Benefits

• Excellent cosmetic outcomes with minimal visible scarring.

• Outpatient procedure performed under local anesthesia.

• Immediate removal of prominent varicosities.

• Rapid recovery and early return to normal activities.
• High patient satisfaction and durable symptom improvement.[23]

Minimally Invasive Approaches

Endovenous Laser Ablation (EVLA)

Endovenous Laser Ablation (EVLA) is one of the most widely utilized minimally invasive treatments for chronic venous insufficiency and superficial venous reflux. The technique employs laser-generated thermal energy delivered through an intravascular fiber to induce endothelial destruction, collagen contraction, vein wall fibrosis, and permanent vein occlusion.[24] EVLA has largely replaced conventional vein stripping in many vascular centers because of its minimally invasive nature and excellent long-term effectiveness.

Technique

The procedure is performed under ultrasound guidance. Following percutaneous venous access, a laser fiber is advanced into the incompetent vein and positioned near the saphenofemoral or saphenopopliteal junction. Tumescent anesthesia is then infiltrated around the target vein to provide analgesia, compress the vein around the fiber, and protect adjacent tissues from thermal injury. Controlled laser energy is subsequently delivered while the catheter is gradually withdrawn, resulting in thermal ablation and vein closure.[25]

Outcomes

Multiple prospective studies and meta-analyses have demonstrated occlusion rates exceeding 90–95%, accompanied by significant reductions in symptoms and improvements in quality-of-life measures. Modern 1470-nm laser systems utilizing radial fibers have shown superior efficacy with lower postoperative pain and bruising compared with earlier laser technologies. Long-term studies report sustained vein closure, low recurrence rates, and durable clinical benefits extending beyond five years.[26]

Complications

- Ecchymosis and localized bruising.
- Transient paresthesia due to thermal irritation of adjacent nerves.
- Superficial thrombophlebitis.
- Skin burns (uncommon).
- Endovenous heat-induced thrombosis (EHIT), a rare but recognized complication.[27]

Radiofrequency Ablation (RFA)

Radiofrequency Ablation (RFA) is another established endovenous thermal technique used to treat incompetent superficial veins. The procedure utilizes radiofrequency-generated thermal energy to denature collagen within the vein wall, causing controlled contraction, collapse, and eventual fibrosis of the treated vein.[28]

Advantages

- Less postoperative pain compared with traditional surgery.
- Reduced bruising and tissue trauma.
- Faster recovery and return to daily activities.
- Excellent cosmetic outcomes.
- High levels of patient satisfaction.

Outcomes

Numerous randomized trials and long-term observational studies have demonstrated closure rates comparable to EVLA, frequently exceeding 90% during extended follow-up periods. RFA is associated with lower postoperative discomfort, reduced analgesic requirements, and shorter recovery times than conventional high ligation and stripping. Consequently, it has become a preferred treatment option for many patients with saphenous vein incompetence.[29]

Ultrasound-Guided Foam Sclerotherapy (UGFS)

Ultrasound-Guided Foam Sclerotherapy (UGFS) involves the injection of a sclerosant foam directly into refluxing veins under real-time ultrasound visualization. The foam displaces intraluminal blood and promotes endothelial injury, resulting in vein fibrosis and eventual occlusion. UGFS is particularly useful for treating recurrent varicose veins, tortuous venous segments, and patients who may not be ideal candidates for thermal ablation procedures.

Advantages

- Office-based procedure requiring minimal equipment.
- No surgical incisions.
- Suitable for recurrent varicose veins.
- Can be repeated when necessary.
- Minimal recovery time.

Limitations

- Higher recurrence rates compared with thermal ablation.
- Multiple treatment sessions may be required.
- Variable long-term durability.
- Risk of pigmentation and superficial thrombophlebitis.

Although UGFS provides satisfactory short-term symptom relief and clinical improvement, long-term recurrence rates are generally higher than those observed following EVLA or RFA, particularly in larger truncal veins.[30]

Mechanochemical Ablation (MOCA)

Mechanochemical Ablation (MOCA) represents a non-thermal, non-tumescent treatment modality that combines mechanical endothelial disruption with simultaneous administration of a liquid sclerosant. Rotational injury to the vein wall enhances sclerosant penetration and promotes effective vein closure without the need for thermal energy.

Advantages

- No thermal injury to surrounding tissues.
- No requirement for tumescent anesthesia.
- Reduced procedural discomfort.
- Short treatment duration.
- Rapid post-procedure recovery.

Five-year follow-up studies have demonstrated favorable clinical outcomes and acceptable long-term occlusion rates, supporting MOCA as a viable alternative for patients seeking minimally invasive treatment without thermal-related complications.

Cyanoacrylate Closure (CAC)

Cyanoacrylate Closure (CAC) is a novel non-thermal and non-tumescent endovenous treatment that utilizes a proprietary medical adhesive to permanently seal refluxing veins. The technique eliminates the need for thermal energy and extensive anesthesia while achieving effective venous occlusion.

Procedure

Under ultrasound guidance, a delivery catheter is advanced into the incompetent vein. Small aliquots of cyanoacrylate adhesive are administered along the vein while external compression is applied, resulting in immediate vein closure and subsequent fibrosis.

Advantages

- No tumescent anesthesia.
- No thermal injury.
- Rapid procedure duration.
- Minimal postoperative discomfort.
- Immediate ambulation and recovery.

Treatment Modality	Advantages
HL/S	Durable results; effective reflux control; suitable for extensive disease.
Ambulatory Phlebectomy	Excellent cosmesis; local anesthesia; quick recovery.
EVLA	Minimally invasive; high success rate; long-term efficacy.
RFA	Less pain; faster recovery; good cosmetic outcome.
UGFS	Office procedure; no incision; minimal downtime.
MOCA	No thermal injury; less discomfort; rapid recovery.
CAC	No anesthesia infiltration; minimal pain; immediate ambulation.

Outcomes

Recent multicenter trials and long-term follow-up studies have reported vein closure rates exceeding 90%, with substantial improvements in Venous Clinical Severity Score (VCSS) and quality-of-life outcomes. Comparative analyses indicate efficacy comparable to established thermal ablation techniques while offering enhanced procedural convenience and patient comfort.

Complications

- Local inflammatory reactions.
- Superficial phlebitis.
- Mild tenderness along the treated vein.
- Rare hypersensitivity reactions to adhesive components.

Overall, CAC represents a promising advancement in the management of chronic venous insufficiency and continues to gain acceptance as an effective alternative to thermal ablation therapies.

Outcomes of Surgical and Minimally Invasive Treatments

Anatomical Success

The primary objective of any intervention for chronic venous insufficiency is the elimination of pathological venous reflux and restoration of efficient venous hemodynamics. Advances in endovenous technology have significantly improved anatomical success rates, with most contemporary minimally invasive procedures achieving vein closure rates exceeding 90%.[31] Numerous prospective studies and systematic reviews have confirmed that Endovenous Laser Ablation (EVLA) and Radiofrequency Ablation (RFA) provide highly durable long-term outcomes, with sustained occlusion of treated veins and low rates of recanalization during extended follow-up periods.[32]

Cyanoacrylate Closure (CAC) and Mechanochemical Ablation (MOCA) have emerged as effective non-thermal alternatives with encouraging medium- and long-term results. Current evidence suggests that these techniques achieve anatomical success rates comparable to thermal ablation in appropriately selected patients, although longer follow-up data continue to accumulate.[33] The high success rates observed with modern endovenous interventions have contributed substantially to their widespread adoption as first-line treatment options for superficial venous reflux.

Symptom Relief

Successful treatment of chronic venous insufficiency is consistently associated with significant improvement in patient-reported symptoms and functional status. Reduction of venous hypertension following intervention alleviates many of the characteristic manifestations of chronic venous disease, resulting in substantial clinical benefit.[34]

Patients frequently report improvement in:

- Leg pain and aching.
- Sensations of heaviness and limb fatigue.
- Lower-extremity swelling and edema.
- Night cramps and restless legs.
- Discomfort associated with prolonged standing.

Several studies have demonstrated marked reductions in Venous Clinical Severity Score (VCSS) and substantial improvements in disease-specific quality-of-life measures following successful intervention.[35] Improvements are often evident within weeks of treatment and may

continue over several months as venous function stabilizes and inflammatory changes gradually resolve.

Recovery

One of the major advantages of minimally invasive therapies is their favorable postoperative recovery profile compared with conventional surgery. Endovenous procedures are generally performed under local anesthesia in an outpatient setting, minimizing procedural trauma and facilitating rapid mobilization.[36]

Compared with traditional surgical stripping, minimally invasive techniques provide:

- Earlier ambulation after treatment.
- Less postoperative pain and discomfort.
- Reduced bruising and wound complications.
- Faster return to work and routine activities.
- Improved cosmetic outcomes.
- Greater patient satisfaction.

The reduced recovery burden associated with endovenous interventions has contributed significantly to their increasing popularity among both patients and healthcare providers. Consequently, contemporary international guidelines generally recommend endovenous ablation as the preferred treatment approach whenever anatomically feasible and clinically appropriate.[37]

Recurrence

Despite substantial advances in treatment technology, recurrence remains an important challenge in the long-term management of chronic venous insufficiency. Recurrent varicose veins may develop due to a variety of mechanisms, including technical, anatomical, and disease-related factors.[38]

Common causes of recurrence include:

- Neovascularization around previously treated venous junctions.
- Incomplete treatment of refluxing venous segments.
- Progressive development of new venous incompetence.
- Recanalization of previously occluded veins.
- Failure to identify contributing perforator or deep venous reflux.

Long-term comparative studies indicate that recurrence rates tend to be lowest following EVLA and RFA among currently available minimally invasive techniques. Continued surveillance and individualized management strategies remain essential to maintaining durable clinical outcomes and minimizing disease progression.[39]

Recent Advances in Management

Advanced Laser Technologies

Technological innovations have significantly enhanced the safety and efficacy of endovenous laser treatment. Modern laser systems operating at wavelengths of 1470 nm and higher are characterized by improved absorption by water within the vein wall, resulting in more targeted energy delivery and reduced collateral tissue damage. These newer systems are associated with lower postoperative pain, less bruising, reduced inflammation, and improved patient comfort compared with earlier laser generations.[40]

The introduction of radial fiber technology has further improved treatment precision by enabling circumferential energy distribution within the vein lumen. This advancement promotes uniform vein wall injury and contributes to high occlusion rates with fewer adverse effects.

Non-Thermal Non-Tumescent (NTNT) Therapies

The development of non-thermal, non-tumescent (NTNT) treatment modalities represents one of the most important recent advancements in venous intervention. Techniques such as MOCA and cyanoacrylate closure eliminate the need for thermal energy and multiple tumescent anesthetic injections, thereby simplifying procedural workflows and enhancing patient comfort.

NTNT therapies are particularly beneficial for patients with needle anxiety, those seeking shorter procedure times, and individuals at increased risk of thermal nerve injury. Growing clinical experience and accumulating long-term outcome data continue to support their role as effective alternatives to thermal ablation procedures.

Image-Guided Precision Treatment

Advances in duplex ultrasonography have revolutionized treatment planning and procedural accuracy in chronic venous disease. High-resolution ultrasound imaging allows precise identification of reflux sources, detailed venous mapping, and real-time procedural guidance.

This image-guided approach facilitates individualized treatment strategies tailored to each patient's venous anatomy and disease pattern. Enhanced diagnostic precision improves treatment efficacy, reduces unnecessary interventions, and contributes to better long-term outcomes.

Combined Treatment Strategies

Modern venous practice increasingly emphasizes comprehensive treatment strategies that address both truncal reflux and visible varicosities. Combined approaches frequently integrate truncal vein ablation with ambulatory phlebectomy, foam sclerotherapy, or both to maximize clinical and cosmetic results.

By treating the underlying source of venous reflux while simultaneously eliminating superficial varicosities, combined treatment protocols can provide superior symptom relief, improved aesthetic outcomes, and higher patient satisfaction. This integrated approach has become a cornerstone of contemporary chronic venous insufficiency

management and reflects the ongoing evolution toward personalized, patient-centered care.

Future Directions

The future of chronic venous insufficiency (CVI) management is expected to be driven by technological innovation, personalized medicine, and a deeper understanding of venous pathophysiology. One of the most promising developments is the adoption of personalized treatment algorithms that integrate venous anatomy, hemodynamic characteristics, patient-specific risk factors, and disease severity to optimize therapeutic decision-making. Advances in artificial intelligence (AI) and machine learning may further enhance diagnostic accuracy by assisting clinicians in the interpretation of duplex ultrasound images, enabling more precise identification of reflux patterns and treatment targets.

Research is also focused on improving non-thermal, non-tumescent (NTNT) therapies through the development of next-generation cyanoacrylate adhesives with enhanced biocompatibility, reduced inflammatory responses, and improved long-term durability. In parallel, bioengineered venous valve reconstruction techniques are being investigated as potential solutions for restoring physiological venous function in patients with advanced valvular incompetence. Emerging regenerative medicine approaches, including stem cell therapy, tissue engineering, and gene-based interventions, may offer novel strategies for correcting venous wall dysfunction and preventing disease progression at the molecular level.

Furthermore, large-scale comparative effectiveness studies are needed to evaluate the long-term performance of various NTNT therapies and establish evidence-based treatment recommendations. The integration of wearable health technologies and remote monitoring systems may also transform postoperative care by enabling continuous assessment of patient activity, symptom progression, treatment adherence, and early detection of complications. Collectively, these innovations have the potential to improve clinical outcomes, enhance patient satisfaction, and redefine the future management of chronic venous insufficiency.

DISCUSSION

The management of chronic venous insufficiency (CVI) has undergone a remarkable transformation over the past two decades, largely driven by advances in endovenous technologies and a growing emphasis on patient-centered care. Historically, high ligation and stripping constituted the cornerstone of treatment for symptomatic superficial venous reflux. Although effective in eliminating reflux and improving symptoms, conventional surgery was frequently associated with postoperative pain, bruising, longer recovery periods, and a higher burden of procedure-related morbidity.[41] The emergence of minimally invasive endovenous therapies has significantly altered the therapeutic landscape by providing effective alternatives that achieve comparable or superior clinical outcomes with improved patient comfort and reduced procedural invasiveness.

Among currently available treatment modalities, Endovenous Laser Ablation (EVLA) and Radiofrequency Ablation (RFA) remain the most extensively investigated interventions. Multiple randomized controlled trials and long-term observational studies have demonstrated high vein occlusion rates, sustained symptom relief, and durable improvements in quality of life following both procedures.[42,43] Furthermore, comparative analyses have shown that EVLA and RFA are associated with lower postoperative pain scores, reduced recovery times, and earlier return to normal activities when compared with conventional surgical stripping.[44] These advantages have contributed to the widespread adoption of endovenous thermal ablation as the preferred first-line treatment for symptomatic saphenous vein incompetence in many healthcare systems worldwide.

The development of non-thermal, non-tumescent (NTNT) techniques represents another significant advancement in venous intervention. Mechanochemical Ablation (MOCA) and Cyanoacrylate Closure (CAC) have expanded treatment options for patients who may wish to avoid multiple tumescent anesthetic injections or are at increased risk of thermal nerve injury.[45] Early and mid-term clinical studies have reported encouraging anatomical closure rates, significant symptom improvement, and high levels of patient satisfaction with these technologies.[46] While long-term outcome data are still evolving, current evidence suggests that NTNT therapies may offer efficacy comparable to thermal ablation in appropriately selected patients while enhancing procedural convenience and patient experience.

Despite these advances, recurrence remains an important clinical challenge. Recurrent varicose veins may arise due to neovascularization, progression of venous disease, untreated perforator incompetence, or recanalization of previously treated veins.[47] Contemporary management strategies increasingly emphasize comprehensive preoperative duplex ultrasound mapping and individualized treatment planning to minimize recurrence and optimize long-term outcomes. In addition, combined treatment approaches incorporating truncal ablation with ambulatory phlebectomy or foam sclerotherapy have demonstrated improved symptom control and superior cosmetic results in selected patients.[48]

Current international guidelines strongly support endovenous intervention as the preferred treatment strategy for most patients with superficial venous

reflux because of its favorable balance between efficacy, safety, and recovery.[49] Nevertheless, conventional surgery continues to play a valuable role in selected complex anatomical situations, recurrent disease, and cases where endovenous approaches may not be technically feasible.[50] Future research should focus on refining patient selection criteria, evaluating long-term comparative effectiveness among emerging technologies, reducing recurrence rates, and developing personalized treatment algorithms based on individual venous anatomy, hemodynamics, and patient-specific clinical characteristics.

CONCLUSION

Chronic venous insufficiency is a prevalent and progressive vascular disorder associated with substantial morbidity and impaired quality of life. Advances in minimally invasive technologies have transformed management, with endovenous laser ablation and radiofrequency ablation becoming preferred treatment modalities for symptomatic venous reflux. Newer non-thermal techniques such as mechanochemical ablation and cyanoacrylate closure further expand therapeutic options. Current evidence supports the superiority of endovenous interventions over traditional surgery in terms of recovery, patient satisfaction, and overall clinical outcomes. Continued technological innovation and long-term outcome studies will further refine the management of CVI and improve patient care.

REFERENCES

1. Eberhardt RT, Raffetto JD. Chronic venous insufficiency. Circulation. 2014;130(4):333-346.
2. Beebe-Dimmer JL, Pfeifer JR, Engle JS, Schottenfeld D. The epidemiology of chronic venous insufficiency and varicose veins. Ann Epidemiol. 2005;15(3):175-184.
3. Robertson L, Evans C, Fowkes FG. Epidemiology of chronic venous disease. Phlebology. 2008;23(3):103-111.
4. Carradice D. Clinical presentation and impact of varicose veins. Br J Surg. 2011;98(5):618-628.
5. Raffetto JD, Mannello F. Pathophysiology of chronic venous disease. Int Angiol. 2014;33(3):212-221.
6. Nicolaides AN. Investigation of chronic venous insufficiency: A consensus statement. Circulation. 2000;102(20):E126-E163.
7. Dwerryhouse S, Davies B, Harradine K, Earnshaw JJ. Stripping the long saphenous vein reduces recurrence after varicose vein surgery. J Vasc Surg. 1999;29(4):589-592.
8. Gloviczki P, Comerota AJ, Dalsing MC, et al. The care of patients with varicose veins and associated chronic venous diseases. J Vasc Surg. 2011;53(5 Suppl):2S-48S.
9. van den Bos RR, Arends L, Kockaert M, Neumann M, Nijsten T. Endovenous therapies of lower extremity varicosities: A meta-analysis. J Vasc Surg. 2009;49(1):230-239.
10. O'Donnell TF Jr, Passman MA, Marston WA, et al. Management of venous leg ulcers: Clinical practice guidelines of the Society for Vascular Surgery and the American Venous Forum. J Vasc Surg. 2014;60(2 Suppl):3S-59S.
11. Bergan JJ, Schmid-Schönbein GW, Smith PD, Nicolaides AN, Boisseau MR, Eklof B. Chronic venous disease. N Engl J Med. 2006;355(5):488-498.
12. Meissner MH. Lower extremity venous anatomy. Semin Intervent Radiol. 2005;22(3):147-156.
13. Coleridge Smith PD. The causes of skin damage and leg ulceration in chronic venous disease. Int J Low Extrem Wounds. 2006;5(3):160-168.
14. Pascarella L, Schmid-Schönbein GW, Bergan JJ. An animal model of venous hypertension: The role of inflammation in venous valve deterioration. J Vasc Surg. 2005;41(2):303-311.
15. Valencia IC, Falabella A, Kirsner RS, Eaglstein WH. Chronic venous insufficiency and venous leg ulceration. J Am Acad Dermatol. 2001;44(3):401-421.
16. Eklof B, Rutherford RB, Bergan JJ, Carpentier PH, Gloviczki P, Kistner RL, et al. Revision of the CEAP classification for chronic venous disorders. J Vasc Surg. 2004;40(6):1248-1252.
17. Lurie F, Passman M, Meisner M, Dalsing M, Masuda E, Welch H, et al. The 2020 update of the CEAP classification system. J Vasc Surg Venous Lymphat Disord. 2020;8(3):342-352.
18. Labropoulos N, Tiongson J, Pryor L, Tassiopoulos AK, Kang SS, Mansour MA, et al. Definition of venous reflux in lower-extremity veins. J Vasc Surg. 2003;38(4):793-798.
19. De Maeseneer MG, Kakkos SK, Aherne T, Baekgaard N, Black S, Blomgren L, et al. Editor's Choice—European Society for Vascular Surgery guidelines on management of chronic venous disease. Eur J Vasc Endovasc Surg. 2022;63(2):184-267.
20. Vasquez MA, Rabe E, McLafferty RB, Shortell CK, Marston WA, Gillespie D, et al. Revision of the Venous Clinical Severity Score: Venous Outcomes Consensus Statement. J Vasc Surg. 2010;52(5):1387-1396.

21. Weiss RA, Weiss MA. Ambulatory phlebectomy: Office management of varicose veins. Dermatol Surg. 1998;24(4):459-463.
22. Almeida JI, Kaufman J, Göckeritz O, Chopra P, Evans MT, Hoheim DF, et al. Radiofrequency endovenous closureFAST versus laser ablation for the treatment of great saphenous reflux. Phlebology. 2009;24(6):263-270.
23. Monahan DL. Ambulatory phlebectomy. Semin Intervent Radiol. 2005;22(3):218-224.
24. Min RJ, Khilnani NM, Zimmet SE. Endovenous laser treatment of saphenous vein reflux. J Vasc Interv Radiol. 2003;14(8):991-996.
25. Proebstle TM, Gul D, Kargl A, Knop J. Endovenous laser treatment of the greater saphenous vein with a 940-nm diode laser. Dermatol Surg. 2004;30(5):729-734.
26. Doganci S, Demirkilic U. Comparison of 980 nm laser and 1470 nm laser in endovenous treatment of great saphenous vein insufficiency. Eur J Vasc Endovasc Surg. 2010;40(2):254-259.
27. Kabnick LS. Outcome of different endovenous laser wavelengths for great saphenous vein ablation. J Vasc Surg. 2006;43(1):88-93.
28. Merchant RF, Pichot O. Long-term outcomes of endovenous radiofrequency obliteration of saphenous reflux. Eur J Vasc Endovasc Surg. 2005;30(6):692-695.
29. Lurie F, Creton D, Eklof B, Kabnick LS, Kistner RL, Pichot O, et al. Prospective randomized study of endovenous radiofrequency obliteration versus ligation and vein stripping. J Vasc Surg. 2003;38(2):207-214.
30. Myers KA, Jolley D, Clough A, Kirwan J. Outcome of ultrasound-guided sclerotherapy for varicose veins. Br J Surg. 2007;94(2):167-173.
31. Rasmussen LH, Lawaetz M, Bjoern L, Vennits B, Blemings A, Eklof B. Randomized clinical trial comparing endovenous laser ablation, radiofrequency ablation, foam sclerotherapy and surgical stripping for great saphenous varicose veins. Br J Surg. 2011;98(8):1079-1087.
32. He G, Zheng C, Yu MA, Li X. Comparison of ultrasound-guided foam sclerotherapy and endovenous laser ablation in the treatment of varicose veins: A meta-analysis. Int J Surg. 2015;13:189-196.
33. Boersma D, Kornmann VN, van Eekeren RR, de Vries JP, Reijnen MM. Treatment modalities for small saphenous vein insufficiency: Systematic review and meta-analysis. J Endovasc Ther. 2016;23(1):199-211.
34. Darwood RJ, Theivacumar N, Dellagrammaticas D, Mavor AI, Gough MJ. Randomized clinical trial comparing endovenous laser ablation with surgery for great saphenous varicose veins. Br J Surg. 2008;95(3):294-301.
35. Kheirelseid EA, Crowe G, Sehgal R, Liakopoulos D, Bela H, Mulkern E, et al. Systematic review and meta-analysis of randomized controlled trials evaluating treatment modalities for varicose veins. Br J Surg. 2018;105(13):1751-1767.
36. Brittenden J, Cotton SC, Elders A, Ramsay CR, Norrie J, Burr J, et al. Clinical effectiveness and cost-effectiveness of foam sclerotherapy, endovenous laser ablation, and surgery for varicose veins. N Engl J Med. 2014;371(13):1218-1227.
37. Wittens C, Davies AH, Bækgaard N, Broholm R, Cavezzi A, Chastanet S, et al. Management of chronic venous disease: Clinical practice guidelines of the European Society for Vascular Surgery. Eur J Vasc Endovasc Surg. 2015;49(6):678-737.
38. Perrin MR, Labropoulos N, Leon LR Jr. Presentation of the patient with recurrent varices after surgery (REVAS). J Vasc Surg. 2006;43(2):327-334.
39. Wallace T, El-Sheikha J, Nandhra S, Carradice D, Chetter IC. Long-term outcomes of endovenous interventions for varicose veins. Phlebology. 2018;33(1):14-22.
40. Disselhoff BC, der Kinderen DJ, Kelder JC, Moll FL. Five-year results of a randomized clinical trial of endovenous laser ablation versus conventional surgery for great saphenous varicose veins. Br J Surg. 2011;98(8):1107-1111.
41. Winterborn RJ, Foy C, Earnshaw JJ. Causes of varicose vein recurrence: Late results of a randomized controlled trial of stripping the long saphenous vein. J Vasc Surg. 2004;40(4):634-639.
42. Christenson JT, Gueddi S, Gemayel G, Bounameaux H. Prospective randomized trial comparing endovenous laser ablation and surgery for treatment of primary great saphenous varicose veins. Br J Surg. 2010;97(3):288-294.
43. Gale SS, Lee JN, Walsh ME, Wojnarowski DL, Comerota AJ. A randomized controlled trial of radiofrequency ablation versus surgical treatment for superficial

venous insufficiency. Ann Vasc Surg. 2010;24(7):887-894.
44. Biemans AA, Kockaert M, Akkersdijk GP, van den Bos RR, de Maeseneer MG, Nijsten T. Comparing endovenous laser ablation, foam sclerotherapy, and conventional surgery for great saphenous varicose veins. J Vasc Surg. 2013;58(3):727-734.
45. O'Banion LA, Reynolds KB, Kochubey M, Cutler BS. Mechanochemical ablation for treatment of superficial venous insufficiency. Phlebology. 2017;32(5):324-329.
46. Gibson K, Ferris B. Cyanoacrylate closure of incompetent great, small and accessory saphenous veins without post-procedure compression. Phlebology. 2017;32(8):535-543.
47. Fischer R, Chandler JG, Stenger D, Puhan MA, de Maeseneer MG. Recurrent varicose veins after treatment: Mechanisms and prevention. Phlebology. 2014;29(1 Suppl):34-41.
48. Harlander-Locke MP, Lawrence PF, Chandra A, Rigberg DA, DeRubertis BG, Gelabert HA. The impact of concomitant phlebectomy during endovenous ablation on clinical outcomes. J Vasc Surg Venous Lymphat Disord. 2013;1(4):365-371.
49. National Institute for Health and Care Excellence (NICE). Varicose veins: Diagnosis and management. NICE Clinical Guideline CG168. London: NICE; 2013.
50. Allegra C, Antignani PL, Carlizza A. Recurrent varicose veins following surgery and endovenous interventions: Current concepts and treatment strategies. Int Angiol. 2016;35(4):343-352.