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A COMPREHENSIVE ECONOMIC EVALUATION OF MODERN VARICOSE VEIN TREATMENT MODALITIES

Minavarkhujayev Ravshankhuja Raxmatkhuja ugli

Assistant of department General surgery №2, Tashkent Medical Academy

Phlebologist at the "VarikozOFF" Clinic

Abstract: Varicose veins are a prevalent manifestation of chronic venous disease (CVD) and a significant source of morbidity and healthcare costs globally. Historically, surgical ligation and stripping were the mainstay treatments. However, the past two decades have seen the rise of minimally invasive interventions such as endovenous thermal ablation (laser or radiofrequency), sclerotherapy (foam or liquid), and non-thermal, non-tumescent techniques (cyanoacrylate closure, mechanochemical ablation). These procedures differ not only in clinical outcomes—like vein closure rates and patient satisfaction—but also in cost profiles, resource utilization, and cost-effectiveness. This comprehensive review explores the economic burden of varicose veins and analyzes the cost-effectiveness of contemporary treatment options. By synthesizing the available literature and economic studies, this review provides valuable insights for clinicians, policymakers, and payers involved in managing venous disease. The article highlights key methodologies for cost-effectiveness analysis, compares direct and indirect costs, and discusses how different healthcare settings influence cost evaluations. While most interventions have demonstrated favorable cost-effectiveness relative to surgery, nuances remain in areas such as long-term recurrence, the influence of patient comorbidities, and evolving device costs.

1. Introduction

Varicose veins—tortuous, dilated superficial veins commonly found in the lower limbs—are a hallmark of chronic venous disease (CVD) that afflicts an estimated 20–40% of adults worldwide. Although commonly perceived as a cosmetic issue, varicose veins can lead to substantial symptoms (leg pain, heaviness, swelling) and progress to advanced complications (stasis dermatitis, venous ulcers), imposing a considerable quality-of-life (QoL) burden. From an economic standpoint, varicose veins and their advanced sequelae drive up costs for healthcare systems through physician visits, diagnostic tests, procedures, and potential disability from chronic leg problems.

Historically, surgical ligation and stripping was the standard for removing incompetent saphenous veins. However, surgery often entailed longer recovery periods, higher postoperative pain, and greater resource consumption compared to more recent minimally invasive modalities. The last two decades have seen dramatic shifts toward endovenous thermal ablation (EVLA—endovenous laser ablation, or RFA—radiofrequency ablation), foam sclerotherapy, mechanochemical ablation (MOCA), cyanoacrylate vein closure, and improved versions of liquid sclerotherapy. These contemporary options offer similar or higher vein closure rates with reduced downtime, translating into potential productivity gains for patients and cost savings for healthcare systems.

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Cost-effectiveness analyses (CEAs) are integral for determining which interventions yield the most value for money. They compare healthcare interventions not only on clinical outcomes—such as efficacy, safety, or health-related QoL—but also on the costs incurred across the patient journey. For varicose veins, CEAs can help prioritize interventions that deliver high closure rates, minimize complications, and improve QoL while using healthcare resources judiciously.

This article offers a comprehensive overview of the cost-effectiveness data on varicose veins treatments, bridging clinical outcomes with economic evaluations. After discussing the pathophysiological and economic burden of varicose veins, we examine the primary modalities currently available. We then delve into methodological considerations for cost-effectiveness analyses before synthesizing key findings from existing studies. Finally, we highlight gaps in knowledge and propose avenues for future research to ensure that clinical and policy decisions are informed by robust economic evidence.

2. Background: Varicose Veins and Their Economic Burden

Varicose veins develop when superficial vein valves fail, allowing retrograde blood flow and engorgement of vein segments in the lower extremities. Alongside the often-cosmetic complaints (visible, bulging veins), patients may experience significant discomfort, edema, and skin changes. In severe cases, chronic venous insufficiency (CVI) leads to venous stasis ulcers, which are notoriously difficult and expensive to treat.

From an economic standpoint, the costs associated with varicose veins can be bifurcated into:

1. **Direct Costs**: Physician consultations, diagnostic imaging (duplex ultrasound), procedure expenses (operating theatre, device costs, anesthesia), postoperative care (compression stockings, wound care), and treatment of complications (ulcers, infections).
2. **Indirect Costs**: Absenteeism or reduced productivity at work due to pain, leg swelling, or postoperative recovery. In advanced disease, patients may face extended periods off work or job loss, imposing additional societal and economic burdens.

As healthcare budgets strain under the weight of aging populations and diverse chronic illnesses, health policymakers increasingly demand evidence of "value" for any intervention. Cost-effectiveness measures attempt to assign monetary values to clinical and QoL outcomes, guiding which interventions should be prioritized or reimbursed. For varicose veins—commonly managed outside the hospital or in outpatient settings—analyzing cost-effectiveness is a pivotal step to ensure that resources are allocated optimally across large patient populations.

3. Overview of Treatment Modalities

Multiple treatment pathways exist for varicose veins, reflecting the heterogeneous nature of venous disease and the evolving technology:

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3.1 Conservative Management

- **Compression Therapy**: Graduated compression stockings remain a cornerstone for mild symptoms or for patients who cannot undergo invasive procedures. Although compression does not correct underlying venous reflux, it can alleviate symptoms, reduce edema, and help prevent ulcer development.
- **Lifestyle Modifications**: Weight loss, leg elevation, regular walking or exercise, and avoidance of prolonged standing may mitigate symptom severity.

From a cost perspective, conservative measures appear inexpensive in the short term. However, the lack of definitive reflux correction can lead to protracted reliance on stockings and repeated visits, culminating in long-term indirect costs and suboptimal QoL improvement.

3.2 Endovenous Thermal Ablation (EVTA)

Endovenous thermal ablation revolutionized varicose vein treatment by offering a less invasive alternative to surgery:

1. **Endovenous Laser Ablation (EVLA)**: Uses laser energy (wavelengths commonly 810–1470 nm, and newer >1900 nm) to heat and seal the incompetent saphenous vein.
2. **Radiofrequency Ablation (RFA)**: Employs radiofrequency energy to cause controlled thermal injury, leading to vein closure.

Both forms of EVTA typically involve tumescent anesthesia, real-time ultrasound guidance, and immediate ambulation post-procedure. With high closure rates (>90% at 1 year) and rapid return to daily activities, EVTA is often viewed as cost-effective, despite its higher procedural expense compared to conservative therapy.

3.3 Sclerotherapy (Foam and Liquid)

Sclerotherapy involves injecting an irritant solution (sclerosant) into the vein to induce endothelial damage and eventual closure. Two main types:

1. **Liquid Sclerotherapy**: Traditionally employed for smaller reticular or spider veins, though it can treat larger veins in certain circumstances.
2. **Foam Sclerotherapy**: By creating a foam mix with gas (air or CO_2), the sclerosant displaces blood in the vein, achieving more extensive endothelial contact. Foam sclerotherapy has become popular for moderate varicosities or as an adjunct to EVTA for tributaries.

Sclerotherapy is generally less resource-intensive than thermal ablation, but closure rates may be lower for large veins, and repeated sessions could accumulate costs over time.

3.4 Non-Thermal Ablation Techniques

Recent innovations aim to further minimize invasiveness and the need for tumescent anesthesia:

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1. **Cyanoacrylate Closure**: "Superglue" technique where a medical-grade adhesive is delivered into the vein via a catheter, sealing it almost instantly without thermal damage or the need for tumescent fluid.
2. **Mechanochemical Ablation (MOCA)**: Combines mechanical disruption of the vein wall with a sclerosant solution. This approach avoids thermal energy and may reduce postoperative pain.

Such techniques can shorten procedure time and reduce anesthesia requirements. However, new devices may entail higher up-front costs, and long-term cost-effectiveness data are still emerging.

3.5 Surgical Ligation and Stripping

Despite a decline in popularity, surgical ligation and stripping remain an option for extensive disease or for patients who are not candidates for endovenous procedures. However, it often involves general or regional anesthesia, more postoperative pain, and longer recovery. While surgery can be effective at occluding the saphenous vein, higher associated indirect costs (longer recovery time, potential complications) often place it at a disadvantage in contemporary cost-effectiveness analyses.

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4. Methodological Approaches in Cost-Effectiveness Analyses

Assessing the cost-effectiveness of varicose veins treatments requires a systematic framework. Economic evaluations typically address three core questions:

1. How effective is the intervention in improving relevant clinical outcomes (e.g., vein closure, relief of symptoms, QoL)?
2. What are the total costs incurred in delivering the intervention and managing associated complications or recurrences?
3. Does the intervention's incremental cost justify its incremental benefits compared to the next best alternative?

4.1 Definitions and Key Concepts

- **Cost-Effectiveness Analysis (CEA)**: Compares interventions in terms of cost per unit of clinical outcome (e.g., cost per additional successful vein closure).
- **Cost-Utility Analysis (CUA)**: Incorporates patient preferences by using quality-adjusted life years (QALYs) or other utility-based measures, expressing cost per QALY gained.
- **Incremental Cost-Effectiveness Ratio (ICER)**: Represents the difference in costs between two interventions divided by the difference in outcomes, typically QALYs, to show the additional cost per additional unit of benefit.
- **Willingness-to-Pay (WTP) Threshold**: A benchmark indicating how much a healthcare system or society is prepared to pay for one additional QALY. Interventions below this threshold are often considered cost-effective.

4.2 Study Designs and Perspectives

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Economic evaluations can be performed from different perspectives:

- **Payer/Insurance Perspective**: Focuses on direct medical costs reimbursed by an insurer.
- **Societal Perspective**: Includes both direct and indirect costs (e.g., productivity losses). Particularly relevant for varicose veins given the impact on work absenteeism.
- **Institutional/Hospital Perspective**: Considers costs to the hospital or outpatient clinic, which can differ from reimbursement rates.

The perspective shapes which costs are included and how outcomes are valued.

4.3 Direct vs. Indirect Costs

Direct Costs refer to actual expenditures on medical services, medication, devices, staff time, and facility overhead. **Indirect Costs** capture lost productivity, wages, or intangible costs (pain and suffering) that are harder to quantify. For varicose veins—often managed in working-age adults—the burden of indirect costs can be substantial, since less invasive procedures typically reduce the time off work.

4.4 Quality-of-Life (QoL) Measures and Utilities

Many studies incorporate validated venous questionnaires (Aberdeen Varicose Vein Questionnaire—AVVQ, Chronic Venous Insufficiency Questionnaire—CIVIQ) or generic health-related QoL instruments (SF-36, EQ-5D). These measures can be translated into utilities, enabling cost-utility analyses. The difference in pre- and post-treatment utility multiplied by time yields QALYs, a common metric in health economics.

4.5 Time Horizons

Varicose veins can recur over years, so short-term evaluations may underestimate recurrence rates and retreatment costs. Conversely, very long horizons may dilute differences in upfront costs. Most analyses consider 1–5 years, though some extend to 10 years or more.

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5. Evidence on Cost-Effectiveness of Varicose Veins Treatments

The existing literature includes randomized controlled trials (RCTs) with cost-effectiveness arms, prospective observational studies, retrospective cost analyses, and modeling studies. This section synthesizes the primary findings, starting with conservative approaches and moving through more invasive modalities.

5.1 Conservative Approaches

Compression Stockings

- **Efficacy**: Compression alone rarely corrects reflux or improves aesthetic concerns, but it can palliate symptoms and prevent some complications.

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- **Costs**: Stockings represent a relatively low direct expense (usually tens of dollars per pair). However, repeated purchases over many years may add up, and the absence of a definitive anatomical correction can lead to ongoing outpatient visits.
- **Long-Term Findings**: A modeling study by Tisi et al. (2016) found that while compression therapy was inexpensive initially, the cumulative costs rose over time, and clinical outcomes were inferior. Hence, it often performed poorly in cost-utility terms compared to definitive endovenous treatments.

5.2 Endovenous Ablation Methods

Since the 2000s, EVTA has supplanted surgery in many healthcare systems due to its favorable combination of high success rates and minimal downtime.

Radiofrequency Ablation (RFA)

- **Clinical Outcomes**: Large RCTs report closure rates >90% at 1 year, with continued durability beyond 5 years.
- **Cost-Effectiveness**:
  - A UK-based National Institute for Health and Care Excellence (NICE) evaluation concluded that RFA was highly cost-effective compared to surgery, primarily driven by reduced postoperative pain and quicker return to work.
  - Some analyses found RFA to be marginally more expensive than endovenous laser ablation (EVLA) due to the cost of disposable catheters, though incremental cost differences have narrowed as technology has matured.

Endovenous Laser Ablation (EVLA)

- **Clinical Outcomes**: Comparable success rates to RFA. Many meta-analyses demonstrate occlusion rates of 88–96% at 1 year, with minimal complications.
- **Cost-Effectiveness**:
  - EVLA catheters often cost less than RFA's proprietary devices, leading some studies to conclude that EVLA is more cost-effective than RFA for high-volume centers, especially if operating times and sedation requirements are equivalent.
  - However, earlier-generation EVLA with lower wavelengths was associated with slightly higher postoperative pain, which can translate into indirect costs. Newer wavelengths (≥1470 nm) appear to reduce pain and bruising, further improving cost-effectiveness.

Studies that directly compare EVLA, RFA, and surgery generally find both endovenous methods to be cost-effective or even cost-saving relative to surgery, due to shorter procedure times, local anesthesia, immediate ambulation, and reduced lost productivity.

5.3 Sclerotherapy

Liquid Sclerotherapy is frequently used for smaller veins, but it can also treat saphenous trunks in selected cases.

- **Cost Profile**: Sclerosant agents are relatively inexpensive, and the procedure can be performed in an office setting.

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- **Efficacy**: Lower occlusion rates for large veins compared to thermal ablation. Multiple sessions may be required, potentially offsetting initial cost advantages.
- **Cost-Effectiveness**:
  - A Dutch study indicated that while foam sclerotherapy had the lowest upfront cost, the need for repeated treatments slightly eroded this advantage over 2 years.
  - Patients appreciated the minimal invasiveness, but in the long run, repeated sessions could escalate total expenditures.
  - In general, sclerotherapy is considered cost-effective for reticular and spider veins or as an adjunct to ablation for tributaries.

Foam Sclerotherapy for Large Veins

- **Increasingly Common**: Foam sclerotherapy can occlude moderate-diameter saphenous veins but has somewhat lower long-term success (70–85% closure at 1 year in some series).
- **Economic Findings**: Short procedure time and low equipment costs initially appear beneficial. However, higher recurrence or partial recanalization rates might mean repeated sessions. When factoring retreatment, cost savings might diminish compared to EVTA.

5.4 Non-Thermal Ablation (Cyanoacrylate, Mechanochemical)

Newer modalities have emerged that eliminate the need for tumescence:

Cyanoacrylate Closure (CAC)

- **Mechanism**: A medical "superglue" is injected to seal the vein.
- **Cost**: The device kit can be more expensive than standard EVLA or RFA catheters.
- **Outcomes**: Short-term data show closure rates comparable to EVLA or RFA, with minimal postoperative pain. Patients can often forgo post-procedure compression stockings.
- **Cost-Effectiveness**:
  - Early analyses show that although the device cost is higher, the lack of tumescent anesthesia and simpler logistics may reduce staff time.
  - If long-term closure rates prove durable, CAC might be cost-competitive, but more robust data (≥5 years) are needed to confirm stable cost-effectiveness.

Mechanochemical Ablation (MOCA)

- **Mechanism**: A rotating wire disrupts the endothelium while sclerosant is delivered, avoiding thermal damage.
- **Cost**: Catheter systems can be expensive, but tumescent anesthesia is largely unnecessary. This saves procedure time and anesthetic resources.
- **Clinical Efficacy**: Short- to medium-term results are comparable to EVLA, though some studies suggest slightly higher recanalization.
- **Cost-Effectiveness**:
  - Real-world data are limited. The initial capital cost for the MOCA device might be offset by quicker procedures and less sedation, but wide-scale adoption and long-term studies are pending.

5.5 Surgical Approaches

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Despite being a "traditional" method, ligation and stripping still have a role, particularly in complex anatomies or in settings without endovenous technology.

- **Direct Costs**: Operating room fees, anesthesiology, hospital stay (in some cases) can exceed those of office-based endovenous procedures.
- **Indirect Costs**: Longer recovery and increased postoperative complications (e.g., hematomas, nerve injuries) may curtail daily activities for weeks.
- **Economic Evaluations**: Multiple comparative studies (e.g., the CLASS trial) have shown that both EVLA and RFA yield faster recoveries and better cost-effectiveness than surgery over a 1- to 2-year span, primarily due to fewer missed workdays.

5.6 Long-Term Considerations and Recurrence

A critical factor in cost-effectiveness analyses is recurrence. If a particular method yields lower recurrence rates, its initial higher cost might be justified by fewer retreatments and complications down the line. Many cost analyses incorporate modeling to account for the possibility of recanalization, new reflux, or symptom return. Typically, EVTA shows good durability, but even modest differences in recurrence rates can impact final ICER values when considered over a 5–10 year horizon.

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6. Healthcare System Perspectives and Policy Implications

Healthcare systems differ widely in how they reimburse varicose veins procedures. In some countries, endovenous ablation is performed in outpatient clinics with government or insurer reimbursement. In others, coverage may favor older surgical approaches due to legacy reimbursement codes, despite evidence favoring EVTA's cost-effectiveness.

6.1 Reimbursement and Insurance Coverage

- In the United States, third-party payers generally reimburse EVTA, but coverage for newer techniques (cyanoacrylate, MOCA) may lag until more robust evidence is available.
- In many European countries, guidelines from bodies like NICE (UK) or respective vascular societies heavily influence coverage decisions. NICE guidelines endorse endovenous treatments over surgery when feasible, citing both clinical and economic advantages.

6.2 Institutional and Societal Views on Cost Utility

From a hospital's perspective, short procedure times, outpatient settings, and fewer complications can maximize resource use efficiency. Societal perspectives emphasize the advantage of decreased absenteeism and improved QoL. Endovenous procedures typically excel from both vantage points, particularly for working-age individuals.

6.3 Value-Based Care and Bundled Payments

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Emerging payment models in some regions incentivize cost-effective treatments by bundling services. Providers receive a set amount for the entire episode of care (diagnosis to recovery), driving them to choose interventions with lower complication and readmission rates. In such frameworks, endovenous therapies often excel, as their favorable complication profile and swift recovery reduce the likelihood of unplanned costs.

7. Future Trends and Research Gaps

Despite the wealth of clinical and economic data, certain gaps persist:

1. **Long-Term Cost-Effectiveness of Emerging Techniques**: Cyanoacrylate closure and mechanochemical ablation boast promising short-term results, but 5–10 year data are still sparse.
2. **Impact of Recurrence and Repeat Interventions**: More robust modeling is needed to quantify how recanalization events influence cost-effectiveness over extended time horizons, particularly in sclerotherapy and newer ablation methods.
3. **Broader Utility Measurements**: Quality-of-life data specific to new technologies remain limited. Studies employing validated questionnaires (AVVQ, EQ-5D, SF-36) with large, diverse populations would clarify real-world patient experiences.
4. **Cost Variation Across Different Settings**: Procedure costs vary substantially between private clinics, public hospitals, and different countries. Local resource availability, labor costs, device pricing, and reimbursement policies can shift the cost-effectiveness profile significantly.
5. **Societal vs. Healthcare System Perspectives**: While many analyses focus on direct healthcare expenditures, improved work productivity can generate significant societal savings. Future research that robustly captures indirect costs will provide a more holistic view of each modality's value.

8. Conclusion

A robust body of evidence suggests that endovenous thermal ablation techniques (EVLA and RFA) are cost-effective alternatives to traditional surgery for varicose veins. Their higher procedural cost is offset by reduced recovery time, fewer complications, and better patient-reported outcomes, leading to overall cost savings or at least cost neutrality when factoring in indirect costs such as missed work. Foam sclerotherapy can be highly cost-effective for smaller veins or as an adjunct to EVTA, though repeated sessions may be necessary for trunk veins. Emerging methods like cyanoacrylate closure and mechanochemical ablation show promise in preliminary economic evaluations, especially if long-term efficacy data confirm high closure rates and durable benefits.

Clinicians and policymakers must consider multiple variables—disease severity, patient comorbidities, local cost structures, and reimbursement mechanisms—when making treatment decisions. For example, in a system emphasizing hospital-based, fee-for-service reimbursements, direct cost considerations might favor certain procedures, whereas a

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bundled or capitated environment that prioritizes overall resource utilization and patient satisfaction could tilt the balance toward different modalities.

In summary, the consensus from existing cost-effectiveness studies underscores a departure from surgical stripping toward less invasive, more patient-friendly interventions. Endovenous procedures, in particular, consistently demonstrate a favorable balance of high clinical efficacy, improved QoL, and acceptable or superior cost profiles over time. As new technology continues to refine the treatment landscape, and as longer-term data accumulate, cost-effectiveness analyses will remain critical for guiding optimal, evidence-based care in varicose veins management.

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