NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF BIOMEDICAL ENGINEERING

EVALUATING TREATMENT ALTERNATIVES FOR VARICOSE VEINS IN THE LEG

M.Sc. THESIS

Mohammed B. A. ABUDAQQA

Nicosia

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Approval

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I hereby declare that all information, documents, analysis, and, results in this thesis have been collected and presented according to the academic rules and ethical guidelines of the Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

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Mohammed B. A. Abudaqqa

Abstract

EVALUATING TREATMENT ALTERNATIVES FOR VARICOSE VEINS IN THE LEG

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Department of Biomedical Engineering

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Varying degrees of dilated blood vessels in the legs can cause varicose veins. Varicose veins form when the valves within the veins cannot recirculate blood back up to the heart properly. The blood begins to pool within the vein, causing a bulging appearance. Varicose veins are usually harmless but can indicate a more serious health issue. Once it is determined that there is no underlying health concern, a treatment plan can be determined. The varicose vein can cause symptoms such as aching, cramping, or swelling in the legs. Varicose veins have complex pathophysiology that is still being debated. However, it appears to entail a genetic susceptibility, defective valves, weaker arterial walls, and elevated intravenous pressure in the lower or higher limbs. The goal of varicose vein treatment is to reduce the appearance of bulging, unsightly, and at times painful varicose veins, typically on the legs. The main objective of this study is to evaluate several treatment alternatives for smaller and larger varicose veins using important criteria such as cost of treatment, duration of treatment, side effects, recovery time, and benefit. This analysis and ranking were carried out using two commonly used multi-criteria decision-making tools. The fuzzy-preference ranking organization method for enrichment evaluation (PROMETHEE) and the fuzzy-technique for order of preference by similarity to ideal solution (TOPSIS) .

The results of the TOPSIS analysis suggest that sclerotherapy is the highest ranked alternative for the treatment of smaller varicose veins with a performance score of 0.5006.

In comparison, the Endovenous Laser Treatment (EVLT) technique is the best choice for treating larger varicose veins with a performance score of 0.8829. This is similar to the result obtained using the fuzzy PROMETHEE technique, which suggests that sclerotherapy with a net-flow ranking of 0.1605 outclassed other treatment alternatives for the treatment of smaller varicose veins. At the same time, EVLT outperformed radiofrequency ablation and surgery to emerge as the top choice when treating larger varicose veins. This ranking is based on the weights and criteria used for the analysis.

Keywords: Decision-making; Fuzzy PROMETHEE; TOPSIS; Treatment technique; Varicose vein

Özet

EVALUATING TREATMENT ALTERNATIVES FOR VARICOSE VEINS IN THE LEG

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Bacaklarda değişen derecelerde genişlemiş kan damarları varisli damarlara neden olabilir. Varisli damarlar, toplardamarların içindeki valfler kanı kalbe doğru şekilde geri döndüremediğinde oluşur. Kan damar içinde toplanmaya başlar ve şişkin bir görünüme neden olur. Varisli damarlar genellikle zararsızdır ancak daha ciddi bir sağlık sorununa işaret edebilir. Altta yatan bir sağlık sorunu olmadığı belirlendikten sonra bir tedavi planı belirlenebilir. Varisli damar, bacaklarda ağrı, kramp veya şişme gibi semptomlara neden olabilir. Varisli damarların hala tartışılan karmaşık patofizyolojisi vardır. Bununla birlikte, genetik yatkınlık, kusurlu kapakçıklar, daha zayıf arter duvarları ve alt veya üst ekstremitelerde yüksek intravenöz basınç gerektiriyor gibi görünmektedir. Varis tedavisinin amacı, tipik olarak bacaklardaki şişkin, çirkin ve zaman zaman ağrılı varisli damarların görünümünü azaltmaktır. Bu çalışmanın temel amacı, tedavi maliyeti, tedavi süresi, yan etkiler, iyileşme ve fayda gibi önemli kriterleri kullanarak daha küçük ve daha büyük varisler için çeşitli tedavi alternatiflerini değerlendirmektir. Bu analiz ve sıralama, yaygın olarak kullanılan iki çok kriterli karar verme aracı kullanılarak gerçekleştirilmiştir; bulanık tabanlı zenginleştirme değerlendirmeleri için Tercih sıralaması organizasyon yöntemi ve bulanık tabanlı İdeal Çözüme Benzerliğe Göre Tercih Sıralaması Tekniği. TOPSIS analizinin sonuçları, 0.5006 performans skoru ile

daha küçük varislerin tedavisi için skleroterapinin en üst sıradaki alternatif olduğunu göstermektedir.

Buna karşılık, Endovenöz Lazer Tedavisi (EVLT) tekniği, 0.8829'luk bir performans puanı ile daha büyük varisli damarları tedavi etmek için en iyi seçimdir. Bu, 0.1605 net akış sıralamasına sahip skleroterapinin daha küçük varislerin tedavisi için diğer tedavi alternatiflerini geride bıraktığını gösteren PROMETHEE tekniği kullanılarak elde edilen sonuca benzer. Aynı zamanda, EVLT, daha büyük varisli damarları tedavi ederken en iyi seçenek olarak ortaya çıkmak için radyofrekans ablasyon ve cerrahiden daha iyi performans gösterdi. Bu sıralama, analiz için kullanılan kriter ağırlıklarına ve kriterlere dayanmaktadır.

Anahtar Kelimeler: Karar verme; bulanık mantik PROMETHEE; Performans puanı; TOPSİS; Tedavi tekniği; Varisli damar.

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List of Abbreviations

AHP:	Analytic Hierarchy Process
EVLT:	Endovenous laser treatment
RFA:	Radiofrequency ablation
ELECTRE:	Elimination and Choice Expressing Reality
F-DCDM:	Fuzzy Multi-Criteria Decision-Making Process
MCDA:	Multi-Criteria Decision Analysis
MCDM:	Multi-Criteria Decision-Making
PROMETHEE:	Preference Ranking Organization Method for Enrichment of Evaluations
PIS:	Positive Ideal Solutions
NIS:	Negative Ideal Solutions

CHAPTER I
Introduction

Vein valve damage can lead to the development of varicose veins, which are unsightly bulges. Blood flow is hampered as a result. Too much blood builds up in the veins over time. Visible veins that bulge, twist, or protrude under the skin may be noticed. They can also produce symptoms such as hurting, cramping, or swelling in the leg. Varicose veins can develop in any superficial vein, but the most usually affected ones are those in the legs ("Varicose veins - Symptoms and causes", 2021). This is because standing and walking upright puts more strain on the veins in the lower body. Varicose veins and spider veins are typical for many people, and modest variations in varicose veins are only a cosmetic problem. Varicose veins can be painful and inconvenient for others ("Varicose veins - Symptoms and causes", 2021). Varicose veins can sometimes lead to more severe health issues ("Conditions and Diseases", 2021). Varicose veins are primarily caused by a malfunctioning or damaged valve ("Conditions and Diseases", 2021). Venous blood returns from the rest of the body to the heart, whereas arteries carry blood from the heart to the rest of the tissues. This allows the blood to circulate throughout the body. Leg veins must defy gravity to return blood to the heart. As a pump, the lower leg muscles contract, and the elastic walls of the veins aid blood return to the heart. Vein valves open to allow blood to travel toward the heart and close to prevent it from returning. Valves can fail, allowing blood to flow backward and pool in the veins, stretching or twisting them. Fig. 1 shows twisted, dilated varicose veins, most typically found on the lower limbs.

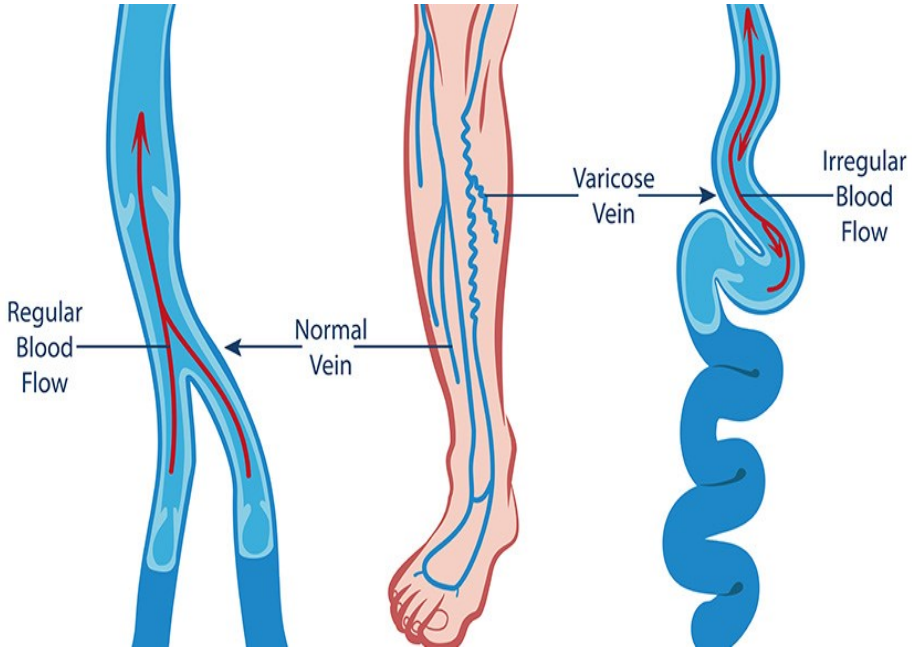

Figure 1.0: Varicose vein in the leg (Min, 2003)

Varicose veins manifest in various ways depending on the patient (Teruya & Ballard, 2004). Asymptomatic patients are those who have no signs or symptoms of the disease. If symptoms are present, they are generally restricted to the area affected by varicose veins; however, they might become more widespread and affect the lower extremities as a whole. Pain, burning, and itching are examples of local symptoms. Leg ache, tiredness, and edema are common symptoms (Villavicencio, 1997). Patients' symptoms improve when they sit and raise their legs, but they return when they stand for an extended amount of time (Villavicencio, 1997). When it comes to symptoms of the lower limbs, women are far more prone than men to talk of heaviness or tension in the legs or swelling or pain (Bradbury et al., 1999). According to the study, there was no correlation between the severity of the varicose veins and the severity of the symptoms. Numerous risk factors for varicose veins have been identified, such as a history of venous illness running in one's family, feminine sex, being obese, or having a job that requires standing for long periods (Beebe-Dimmer et al., 2005). According to current research, no single reason is responsible for varicose veins. However, a family history of weakened blood arteries and increased intravenous pressure has been linked to the problem. Itching or burning and a heavy, achy sensation are all symptoms of varicose veins exacerbated by standing. Complicating factors include the risk of infection, ulceration in the legs, and alterations in stasis and thrombosis (Racette & Sauvageau, 2005).

Even though varicose veins can be painful and unsightly, they rarely have serious medical consequences. There are a variety of possible adverse effects, including a change in skin color, eczema, infection, superficial thrombophlebitis, and venous ulcers (Galland, 2011). External bleeding from a varicose vein perforation is unusual but documented (Racette & Sauvageau, 2005). It is easier to diagnose an illness when risk factors, symptoms, and standard physical exam results are included. Physical examinations are sufficient to diagnose primary varicose veins in most patients, but they do not reveal whether or not the patient has profound venous insufficiency. The value of clinical diagnostics for locating the source of reflux is very low.

Several conservative treatment alternatives include avoiding prolonged standing and straining, elevating the affected limb, exercising, applying external compression, and removing restrictive clothing. Other alternatives include medical therapy, modifying cardiovascular risk factors, and losing weight to reduce peripheral edema. Laser treatment, injectable sclerotherapy, and surgery are examples of more invasive treatments. There is a shortage of information on the comparative effectiveness of different treatment approaches. There isn't much data to suggest that one treatment method is better than another. The symptoms, patient preferences, costs, risk of iatrogenic effects, accessible medical resources, insurance coverage, and physician training influence treatment options.

There is no other way to avoid developing varicose veins in the first place. Improving circulation and muscle tone may help prevent the development of varicose veins. Avoiding varicose veins from forming in the first place can be as simple as regular exercise, weight control, a high-fiber, and low-salt diet, avoiding high heels and tight pantyhose, elevating the legs, and regularly changing sitting or standing position (Bergan, 1995).

The cost of treatment is an important criterion when determining the most preferred alternative for the treatment of varicose veins. Patient consideration of the cost of treatment may warrant them to seek alternative solutions. Hence, the cost must be within an affordable range for it to be accessible. The benefit of a treatment alternative is a critical criterion as any treatment without benefit will never be recommended by a medical expert. Also, the degree of treatment’s benefit can be the ultimate difference between the two treatment alternatives. Medical experts recommend treatment alternatives with great benefits and little or no side effects. The side effect of a treatment alternative is the adverse effect. It

can be acute or chronic. Sometimes it can debilitate and require an additional dose of other medication. Furthermore, the duration of treatment is an important factor to consider when selecting an appropriate alternative for varicose veins. A treatment option with a shorter duration of treatment is mostly preferred than those with a longer duration of alternative.

1.1 Varicose veins

1.1.1 Larger varicose veins

Larger varicose veins are generally treated with litigation, stripping, laser, or radiofrequency treatment. In some cases, a combination of treatments may work (enSanté, 2021).

1.1.2 Smaller varicose veins

Sclerotherapy or laser therapy on the skin is commonly used to treat smaller varicose veins and spider veins. This can make deciding on the best course of treatment more complicated (enSanté, 2021).

1.2 Treatment Alternatives

Considering age, general health, and symptomatology, patients with varicose veins may be offered one or more management options (TenBrook et al., 2004). Treatment may involve self-care measures or procedures by the doctor to close or remove veins. The indications for treatment are primarily based on the severity of pain, patient preference, and physician expertise (Galland, 2011). Patients' symptoms, costs, and risk of iatrogenic problems influence treatment decisions. Other factors include the availability of medical resources and insurance payment. Deep venous insufficiency and the features of the diseased veins can also influence therapy decisions (Galland, 2011). Venous insufficiency can be treated with vascular surgery in patients with leg pain and weariness, swelling in the ankle, early hyperpigmentation, external bleeding, painful ulcers, or superficial thrombophlebitis.

1.2.1 Sclerotherapy

In the case of varicose and spider veins, sclerotherapy is a common non-surgical treatment. A chemical is injected into the superficial veins, and this causes the veins to collapse permanently. Figure 2 shows the procedure of inserting a needle into a vein and injecting a sclerosing material. The material seals and scars the vein by displacing the blood and reacting with the vascular endothelium. All hyperosmotic solutions and corrosive substances are used in this operation, including hypertonic saline, detergent solutions, and sodium tetradecyl

sulfate (such as glycerin). There is no standard vein diameter for use in determining treatment selections; nevertheless, injections work best on 1 to 3 mm or 3 to 5 mm in diameter, depending on the technique used. In addition to relieving the pain, the procedure can also help with other symptoms like aching, swelling, burning, and sleep cramps. Sclerotherapy is a good treatment alternative for minor varicosities because it is cost-efficient and effective. However, this procedure has concerns about DVT development and other eyesight and varicosity-related side effects [13-15].

After sclerotherapy, treated veins tend to fade within a few weeks, although occasionally, it may take a month or more to see the full results. In some instances, several sclerotherapy treatments may be needed. Sclerotherapy has a low risk of significant side effects. Bruising, raised red regions, small skin ulcers, darker skin in the shape of lines or blotches, and numerous tiny red blood vessels are all possible adverse effects at the injection site. It normally takes a few days to a few weeks for these side effects to go away. Some side effects may not go away for months or even years. Sclerotherapy has been used to treat varicose veins for over 150 years (Omura, 2002). In the short term (1 year), sclerotherapy was superior to surgery in terms of treatment success, complication rate, and cost, but surgery was superior in the long run (5 years), even though the research was inadequate (Rigby et al., 2004). According to a Health Technology Assessment, Sclerotherapy isn't as successful as surgery for varicose veins without reflux, although it may provide a little benefit in those circumstances (Michaels et al., 2006). This Health Technology Assessment monograph comprised a review of epidemiology, evaluation, and treatment, as well as a clinical and cost-effectiveness study of surgery and sclerotherapy. It is possible to develop ulcers after sclerotherapy, even though it is pretty infrequent. Doctors should be prepared for life-threatening anaphylactic reactions, which are "extraordinarily rare but can be life-threatening" [20-21]. Using ultrasound guidance, a massive dosage of sclerosant foam was injected into one patient, which resulted in a stroke.

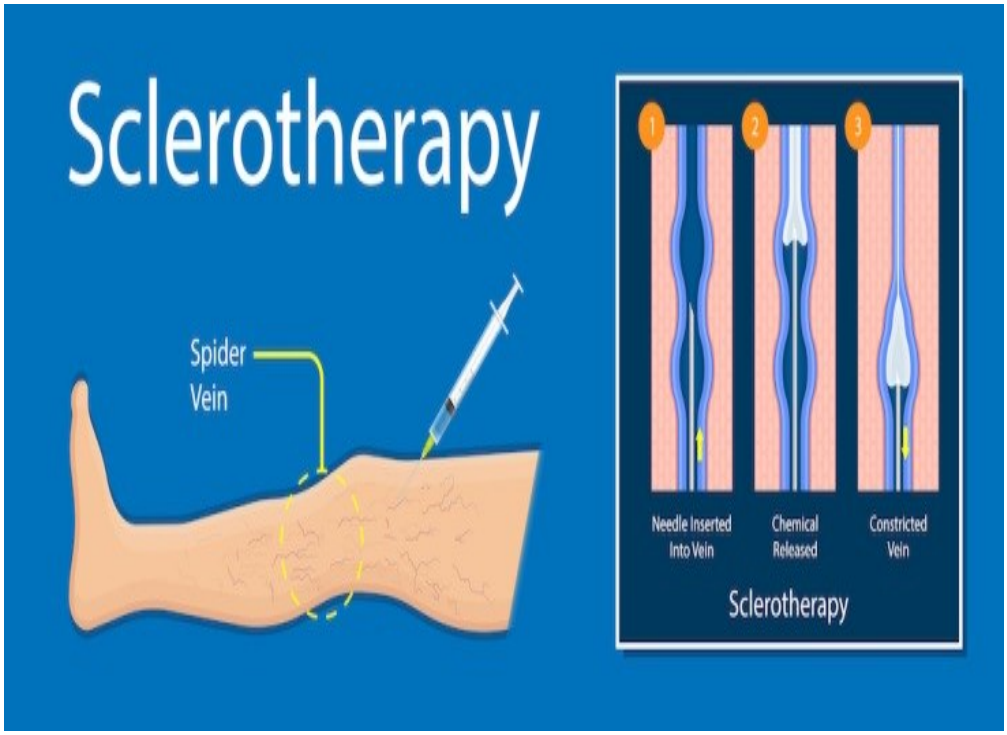

Figure 1.1: Sclerotherapy for varicose vein [3]

1.2.2 Surgery

In the past, surgery has been the most popular treatment for varicose veins, especially when alternative options like endothermal ablation or sclerotherapy are ineffective. On the other hand, the literature does not always support surgery as the only therapy choice (Rigby et al., 2004). Vein ligation and stripping is a minor surgery that permanently removes varicose veins. This technique is typically done under general anesthesia and pulls the entire length of the affected vein. Ligation refers to the cutting and stitching of the vein while stripping refers to the actual removal of the vein.

Vein ligation and stripping are the most invasive methods for varicose vein removal. This treatment typically requires general anesthesia and surgery and can last between 60-90 minutes or longer. The procedure involves removing the affected vein all at once, pulling the vein from the top of the leg through an incision at the knee or the ankle. Ambulatory phlebotomy is similar but requires local anesthetic and removes the vein in smaller sections.

Once the patient is sedated under general anesthesia, two incisions will be made: the first near the groin and the second near the knee or ankle. Incision location will vary depending on the individual needs of the patient. At the incision near the groin, the varicose vein will be located, severed, and stitched at the top. A wire will then be threaded through the entire length of the vein, exiting the body at

the location of the second incision. The vein is removed from the body as the wire is pulled out. Incisions will be closed with sutures. During surgery, it is common to have smaller varicose veins removed. Incisions will be made near the vein, ligated, and surgically removed from the body without the need for a wire. These incisions typically only require adhesive strips for closure. The leg will then be bandaged, and compression stockings may also need to be worn. Full recovery can take up to 4 weeks (Bergan, 1995).

Patients will return home after surgery for recovery. Many can return to work and normal activities within a few days. Compression stockings should be worn 24 hours daily for the first week and during the day for an additional week, although some patients will require compression therapy for up to 4 weeks. Stripping and ligation are not recommended for patients with poor circulation, lymphedema, skin infections, arteriovenous fistulas, or blood-clotting defects. Women who are pregnant are not candidates for the procedure. Side effects from ligation and stripping may include discomfort, bruising, numbness and tingling sensations, infection, blood clots, and irritation of leg nerves.

1.2.3 Endovenous Laser Treatment (EVLT)

This therapy uses laser heat to target and eliminates varicose veins' symptoms. Veins that are swollen and enlarged are known as varicose varices. Legs are the most commonly affected (enSanté, 2021). A thin, flexible tube (catheter) is used to deliver laser-generated heat into the vein during EVLT, as depicted in Figure 4. This prevents blood from flowing through the primary vein that's causing problems. The procedure is guided with the help of an imaging technique like ultrasound. A numbing agent is injected into the leg that will be treated. A small hole (puncture) is made in the vein to be treated after the leg has been made numb with a needle. The laser heat source catheter is placed into a vein. The vein may be numbed with more anesthetic medication. Once the catheter is in the proper location, it is slowly retracted. The vein is sealed off while the catheter emits heat. Through a series of minor cuts, it is possible to get rid of or tie off additional side branch varicose veins (incisions). The catheter is withdrawn following the completion of treatment. To halt any bleeding, firm pressure is applied to the insertion site. After that, the leg may be wrapped in an elastic compression stocking or bandage. The treatment takes 45 to 60 minutes (Barwell et al., 2004). The entire treatment (including time to prepare and recover)

takes about 1 to 3 hours (Campbell, 2006), so the patient can go home the same day.

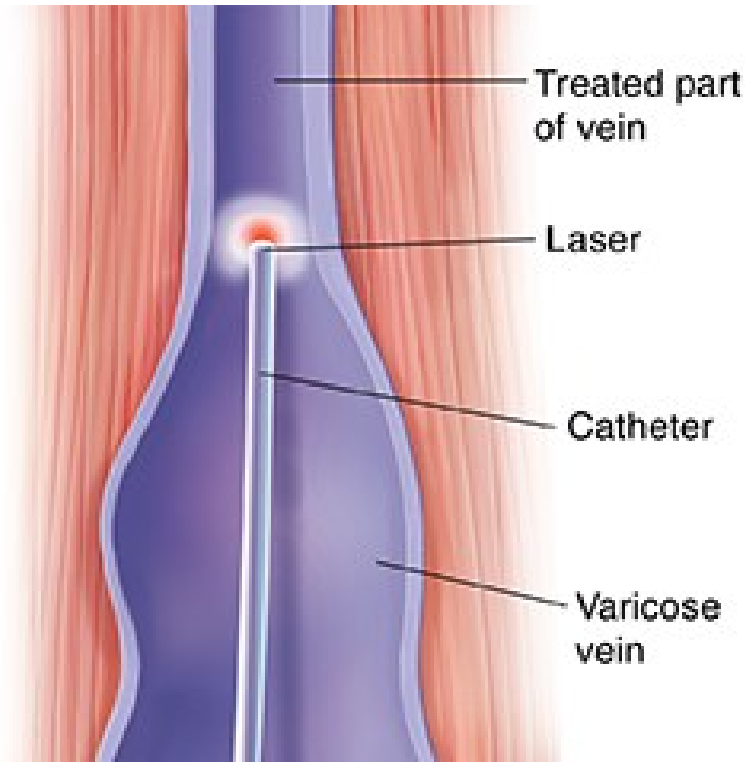

Figure 1.2: Endovenous Laser Treatment (EVLT) procedure ("Krames Online - Endovenous Laser Treatment (EVLT) for Varicose Veins", 2021)

1.2.4 Radiofrequency Ablation

Radiofrequency ablation is a minimally invasive treatment for varicose veins. Radiofrequency ablation (RFA), like endovenous laser ablation (EVLA), uses thermal (heat-based) damage to the vein to close it immediately. After radiofrequency ablation has been used to eliminate the vein, it will eventually be absorbed by the body and fade away.

The radiofrequency catheter is guided by ultrasound into the vein through a tiny incision and advanced to the point where treatment begins. The catheter tip will be positioned about 2 cm from the saphenofemoral junction, as indicated in Figure 5.

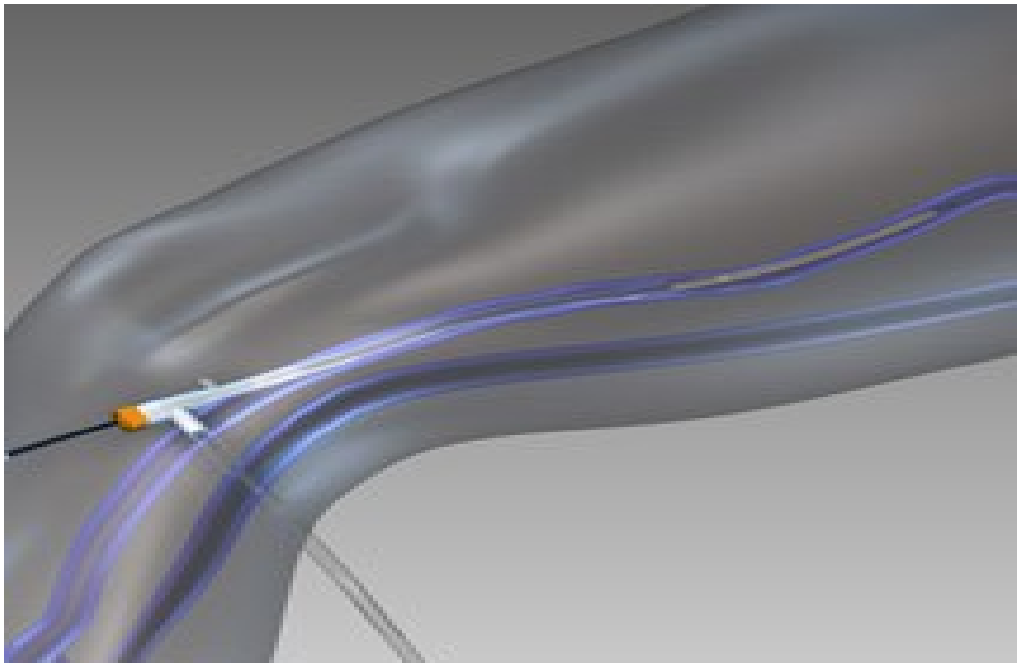

Figure 1.3: Radiofrequency catheter in the vein ("24 Vein clinic near me ideas in 2021 | vein clinic, veins treatment, vein specialist", 2021)

Local anesthetic is injected along the vein's entire length under the supervision of ultrasonography once more. A heat sink shields the surrounding tissue from the radiofrequency fiber to improve patient comfort. This also allows better contact between the radiofrequency fiber and the vein wall. A specially designed RFA fiber delivers RF energy with a 7-centimeter active tip to heat the vein wall. The device is engaged for every 7 cm of vein length for 20 to 40 seconds, making the treatment rapid and painless. The tip of the fiber releases radiofrequency energy, which causes a thermal response in the vein wall along the treated portion, as seen in Figure 6. This causes the vein wall to collapse and sclerosis, with minimum discomfort ("24 Vein clinic near me ideas in 2021 | vein clinic, veins treatment, vein specialist", 2021).

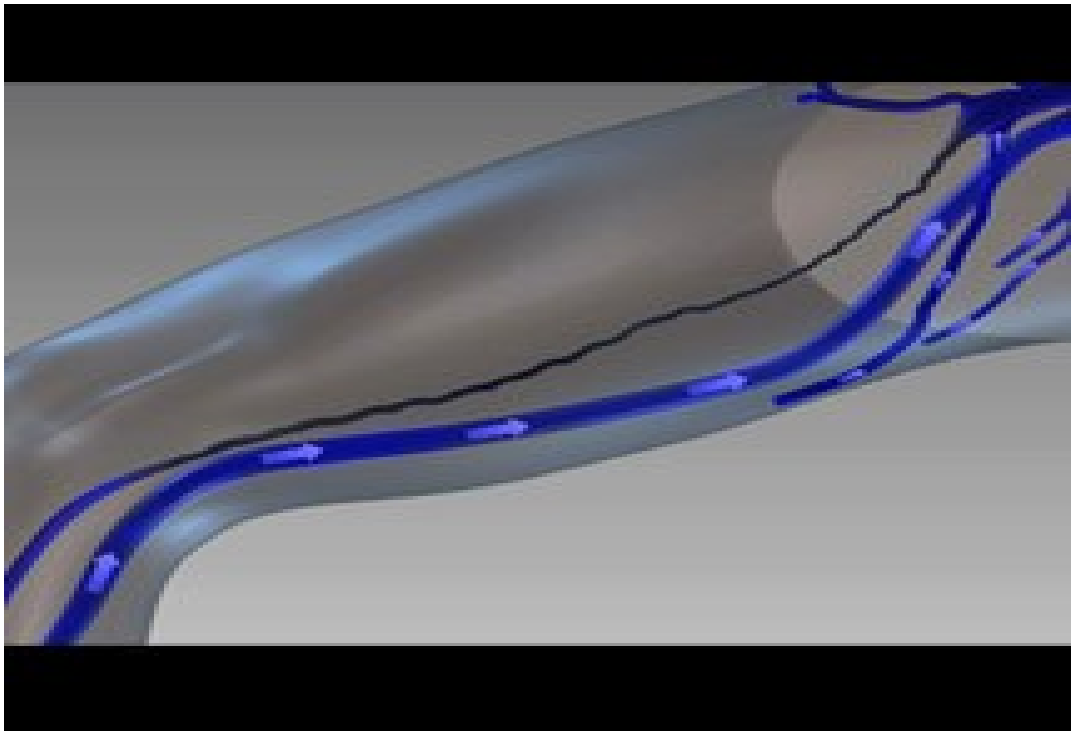

Figure 1.4: sclerosis of the vein wall ("24 Vein clinic near me ideas in 2021 | vein clinic, veins treatment, vein specialist", 2021)

Skin burns, burning, soreness or prickling after recovery, and little or big blood clots in the vein or deep vein are all possible side effects of radiofrequency ablation (less likely than after vein stripping surgery) ("24 Vein clinic near me ideas in 2021 | vein clinic, veins treatment, vein specialist", 2021). Radiofrequency ablation closes off varicose veins in about 88 out of 100 people. That means it doesn't work in about 12 out of 100 people (van den Bos et al., 2009). One great benefit of radiofrequency ablation is that no surgical incision is needed. Only a tiny nick in the skin is required not to be stitched closed.

In this study we have analysed various treatment options of the varicose veins based on their important features such as treatment duration, cost, side effect, benefits and recovery time using multi criteria decision analysis methods.

CHAPTER II

Methodology

2.1 Fuzzy Logic

It is a challenge to collect exact data that accurately reflects real-world situations. Additionally, this difficulty is compounded by the description of ambiguous facts or information that is neither entirely accurate nor entirely untrue. Because of this, Boolean logic is an extremes-based system; a condition is one of the other. It could be true (1) or false (0), without any value in between or uncertainty. On the other hand, Fuzzy logic allows a machine to deal with situations with some uncertainty. If a room is hot or cold, Boolean logic will tell us that, but when does the temperature change from cold to warm? If a decision is ambiguous, fuzzy logic gives the user the option of choosing between extremely chilly, very cold, warm, hot, or very hot.

Fuzzy logic is preferred over other systems like predictable logic (also known as Bayesian logic), Bayesian control (also known as probability theory), and classical theory because it allows for computation using words (Zadeh, 1996).

Numerous researchers have found that fuzzy set theory is also used in commercial expert systems, control devices for trains and elevators, and semiconductor production. Many methods have seen considerable gains in introducing fuzzy logic and fuzzy sets into their manufacturing processes. If the rules aren't precisely defined, this strategy works well with unclear data sets.

Professionals in business and academia are increasingly studying fuzzy logic and associated technologies. This logic can be used for systems and equipment that cannot be adequately defined mathematically, have significant uncertainties or contradicting conditions, and are locally managed. It can also be used in situations when normal logic technologies are inadequate. As previously stated, fuzzy logic will not replace conventional logic (computers) or techniques; instead, it will be used in conjunction with conventional approaches when those fail to produce the desired referans.

2.2 Multi-Criteria Decision-Making (MCDM)

MCDM (multi-criteria decision-making) or MCDA (multi-criteria decision analysis) is a field of study that examines the different possibilities available in a situation or research area to resolve a competing set of objectives. In addition to everyday life, it can be applied in the social sciences, engineering, and medical fields (Zionts, 1979). MCDM is a widely used decision-making technique in various fields (Mardani et al., 2015).

To help the decision-maker choose an option with the fewest compromises and largest benefits, MCDM analyses the alternatives to evaluate whether they are excellent or bad options for a given application. Afterward, it tries to compare these choices according to the specified criteria. Qualitative or quantitative criteria might be used to analyze the indicators.

Two types of MCDM exist based on the weighting technique used to assess the relative relevance of each possibility (Majumder et al., 2018):

Compensatory decision-making: Consider the criteria of each alternative, both strong and weak, and make the substantial features of a particular one to compensate for the less strong ones, so consider all of the alternatives' criteria. Consider the Analytical Hierarchy Process (AHP) to illustrate a compensating decision-making process. This technique is often employed in a complicated analytic setting to compare parameters that are tough to quantify.

Outranking decision-making: To choose the best option, this method evaluates the characteristics of each one side by side (Yang et al., 2012). Popular outranking decision-making approaches include F-MCDM (Fuzzy Multi-Criteria Decision-Making Process). It's used to narrow down, rank, and classify different approaches to an issue.

2.3. Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)

PROMETHEE is an MCDM tool designed to assist users in making better judgments. PROMETHEE performs a comparison of the available options depending on the criteria specified.

For the following reasons, PROMETHEE was selected above other multi-criteria decision-making procedures in this study;

- Qualitative and quantitative criteria can both be taken into consideration.
- It includes several decision-making preference functions for each criterion.
- It's simple to use and gives the user complete control over the weighting of each criterion.

A PROMETHEE consists of two simple requirements: preference functions and importance weight of each criteria (Macharis et al., 2004).

When two alternatives are compared using a single criterion, the preference function describes the assessment difference. The preference degree might range from 0 to 1.

2.3.1. The Steps of the PROMETHEE Method

The PROMETHEE method was used in this study, as described by the method's developers (Brans et al., 1986).

1. For each criterion j, define a distinct preference function p_j (d).
2. Calculate the weight of each criterion using the vector form of w_t = (w_1, w_2,..., w_k). Weight normalization or weight equalization can be determined based on the discretion of the decision-maker
3. For every alternative $a_t, a_{t'} \in A$, determine the outranking relation π.

$$\pi(a_t, a_{t'}) = \sum_{k=1}^{K} w_k . \left[p_k\left(f_k(a_t) - f_k(a_{t'})\right)\right], \qquad AXA \rightarrow [0,1]$$

4. Establish the positive and negative outranking flows;

- Positive outranking flow for a_t: $\Phi^+(a_t) = \frac{1}{n-1}\sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi(a_t, a_{t'})$
- Negative outranking flow for a_t: $\Phi^-(a_t) = \frac{1}{n-1}\sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi(a_{t'}, a_t)$

n refers to the number of alternatives and each alternative is compared to an n-1 number of alternatives.

The positive outranking flow depicts how one alternative outperforms all others. The greater an alternative's positive outranking value, the better it is. The negative outranking flows illustrate how one alternative is outranked by others. The smaller the value of the negative outranking, the better the option.

5. Define the partial pre-order on A's alternatives. In PROMETHEE I alternative a_t is preferred to alternative $a_{t'}$ $(a_t P a_{t'})$ if one of the following requirements is met:

$$(a_t P a_{t'})\ if;$$

$$\begin{cases} \Phi^+(a_t) > \Phi^+(a_{t'})\ and\ \Phi^-(a_t) < \Phi^-(a_{t'}) \\ \Phi^+(a_t) > \Phi^+(a_{t'})\ and\ \Phi^-(a_t) = \Phi^-(a_{t'}) \\ \Phi^+(a_t) = \Phi^+(a_{t'})\ and \Phi^-(a_t) < \Phi^-(a_{t,}a_{t'}) \end{cases}$$

6. Find the alternative with the highest net outranking flow.

$$\Phi^{net}(a_t) = \Phi^+(a_t) - \Phi^-(a_t)$$

The complete pre-order may be derived using the net flow and specified by PROMETHEE II, which makes use of:

a_t is preferred to $a_{t'}$ $(a_t P a_{t'})$ if $\Phi^{net}(a_t) > \Phi^{net}(a_{t'})$

a_t is preferred to $a_{t'}$ $(a_t I a_{t'})$ if $\Phi^{net}(a_t) > \Phi^{net}(a_{t'})$

In other words, the higher the $\Phi^{net}(a_t)$ the better the alternative

2.4 The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was first introduced in 1981 (Yoon & Hwang, 1985). It was later improved in 1987 and 1993 (Yoon, 1987; Hwang et al., 1993).

This research compared numerous varicose vein treatment alternatives using the fuzzy TOPSIS method. TOPSIS assumes that any solution picked by a single decision-maker will be rated and weighted. However, when several decisions must be made, complexity occurs because many different interest groups or individuals must agree on the desired solution. the basic steps of the TOPSIS method is as follows:

Step 1 The decision matrix and weighting of each criterion are constructed.

Step 2 Calculation of the normalized decision matrix

Step 3	Calculate the weighted normalized decision matrix
Step 4	Determination of the positive ideal and negative ideal solutions
Step 5	Calculate the separation measures from the positive ideal solution and the negative ideal solution.
Step 6	Calculate the relative closeness to the positive ideal solution
Step 7	Rank the preference order or select the alternative closest to 1.

Advantages of the TOPSIS include;

a. Computational efficiency.
b. By utilizing normalized values, the distinctions between the alternatives can be displayed (Kraujalienė, 2019).
c. A combination of intuitive and analytical reasoning that guides our actions.

However, the disadvantage of TOPSIS includes;

a. It is challenging to weight while maintaining consistency of judgment.
b. The Euclidean distance is not correlated with characteristics ("Decision Support System Best Employee Assessments with Technique for Order of Preference by Similarity to Ideal Solution", 2017).
c. There is no objective way to rate it (Sharma et al., 2020).

2.5 Application of PROMETHEE to varicose vein treatment technique

The Yager index was used to defuzzify the triangular fuzzy numbers before determining the weight of each criterion. The Yager index has been chosen above other ways because it considers all points and does not alter extreme values and weights considerably.

Table 2.1 indicates the fuzzy triangular scale, which assesses the usefulness of the characteristics in linguistics. The parameters' weights are determined by an expert's judgment, based on the experiences of specialists and other healthcare practitioners with patients with varicose veins and their complications. This criterion also ensures the most important aspects in guaranteeing that patients obtain the best results from a therapy choice. The decision-maker, patient state, and, most crucially, the expert's judgment can influence these weights.

Table 2.1: Linguistic scale of importance

Linguistic scale for evaluation	Triangular fuzzy scale	Importance ratings of criteria
Very high (VH)	(0.75, 1, 1)	Recovery time, Benefit, Side-effect
High (H)	(0.50, 0.75, 1)	Cost of treatment
Medium (M)	(0.25, 0.50, 0.75)	Duration of treatment,
Low (L)	(0, 0.25, 0.50)	-
Very low (VL)	(0, 0, 0.25)	-

Using the PROMETHEE approach, Gaussian preference functions were applied to each of the several criteria used in varicose vein treatment,

resulting in collecting all of the relevant parameters. Table 2.2 lists the various parameters and their characteristic values for the analysis. Because the Gaussian preference function is impervious to the minute and insignificant variations in parameter input values, it was selected above the other preference functions (Parreiras & Vasconcelos, 2007).

Table 2.2: Visual PROMETHEE application for varicose vein treatment

Criteria	Cost of treatment	Duration of treatment	Recovery time	Benefit	Side-effect
Unit	*$*	*Minute*	*Day*	*Impact*	*Impact*
(min/max)	*Min*	*Min*	*Min*	*Max*	*min*
Weight	*0.75*	*0.50*	*0.92*	*0.92*	*0.92*
Preference Fn.	*Gaussian*	*Gaussian*	*Gaussian*	*Gaussian*	*Gaussian*
Sclerotherapy	400	40	14	High (H)	Low (L)
Surgery	2250	75	21	High (H)	High (H)
Endovenous Laser Treatment (EVLT)	1800	52	3	High (H)	Medium (M)
Radiofrequency Ablation	3500	52	6	Very High (VH)	Medium (M)

2.6 Application of TOPSIS to varicose vein treatment technique.

Like the PROMETHE method, a decision matrix is generated, and weight is assigned to all criteria based on their relevance. We utilized the same weight in the PROMETHEE method to the TOPSIS method. This indicates that the criteria have the same importance when considering treatment alternatives to smaller and larger varicose veins.

The normalized matrix is calculated for smaller and larger varicose veins, as shown in table 2.3 and table 2.4.

Table 2.3. Calculated Normalized Matrix of the Smaller Varicose Treatment Alternatives

Alternatives	**Cost of treatment**	**Duration of treatment**	**Recovery time**	**Side-effect**
Sclerotherapy	0.2169	0.6097	0.9778	0.4472
Endovenous Laser Treatment (EVLT)	0.9762	0.7926	0.2095	0.8944

Table 2.4. Calculated Normalized Matrix of the Larger Varicose Treatment Alternatives

Alternatives /Criteria	Cost of treatment	Duration of treatment	Recovery time	Benefit	Side-effect
Surgery	0.4963	0.7140	0.9526	0.5342	0.7276
Endovenous Laser Treatment (EVLT)	0.3970	0.4951	0.1361	0.5342	0.4851

Radiofrequency Ablation	0.7720	0.4951	0.2722	0.6552	0.4851

The several criteria dimensions are integrated into a single dimension to allow comparisons across all criteria. Each component of the matrix must be standardized to make the data comparable. After that, the weighted matrix for smaller and bigger varicose veins have been calculated , which is shown in Tables 2.5 and 2.6 accordingly.

Table 2.5. Calculated Weighted Normalized Matrix of the Smaller Varicose Treatment Alternatives

Alternatives /Criteria	Cost of treatment	Duration of treatment	Recovery time	Side-effect
Sclerotherapy	0.0527	0.0987	0.2911	0.1332
Endovenous Laser Treatment (EVLT)	0.2369	0.1283	0.0624	0.2663

Table 2.6. Calculated Weighted Normalized Matrix of the Larger Varicose Treatment Alternatives

Alternatives /Criteria	Cost of treatment	Duration of treatment	Recovery time	Benefit	Side-effect
Surgery	0.0928	0.0890	0.2185	0.1226	0.1669
Endovenous Laser Treatment (EVLT)	0.0743	0.0617	0.0312	0.1226	0.1113
Radiofrequency Ablation	0.1444	0.0617	0.0624	0.1503	0.1113

The best and worst performances for each criterion are identified to determine the positive ideal solutions (PIS) and negative ideal solutions .

The distance of each alternatives from PIS and NIS are calculated as in table 2.7 or 2.8.

Table 2.7. Identifying the positive and negative ideal solutions for smaller varicose

	Cost of treatment	Duration of treatment	Recovery time	Side-effect
Positive ideal solution (v+)	0.0527	0.0987	0.0624	0.1332
The negative ideal solution (v-)	0.2369	0.1283	0.2911	0.2663

Table 2.8. Identifying the positive and negative ideal solutions for larger varicose

	Cost of treatment	Duration of treatment	Recovery time	Benefit	Side-effect
Positive ideal solution (v+)	0.0743	0.0617	0.0312	0.1503	0.1113
Negative ideal solution (v-)	0.1444	0.0890	0.2185	0.1226	0.1669

This can be accomplished by utilizing a wide range of distance measures. The performance score was derived by calculating the Euclidean distance between PIS and NIS.

MCDM allows users to evaluate and sort different alternatives by their respective criterion, and TOPSIS (Technique for Order Preference by

Similarity to Ideal Solution), a method that that is used in this study to evaluate treatment alternatives for a varicose vein in a patient. This study compared numerous varicose vein treatment alternatives using a fuzzy TOPSIS approach.. However, as previously stated, the fuzzy TOPSIS technique is utilized to validate fuzzy PROMETHEE results.

CHAPTER III

Result

Based on the results of the PROMETHEE study, sclerotherapy is most beneficial and preferable as an alternative for the treatment of smaller varicose veins with a positive outranking flow of 0.3125, a negative outranking flow of 0.2291, and a net outranking flow of 0.0833. With a negative outranking flow of -0.0833, Endovenous Laser Treatment (EVLT) is the least favorable alternative for treating smaller varicose veins, as shown in Table 3.1.

Table 3.1. PROMETHEE Ranking Results for Smaller Varicose Treatment Alternatives

Rank	Alternatives	Phi	Ph+	Phi-
1	Sclerotherapy	0.0833	0.3125	0.2292
2	Endovenous Laser Treatment (EVLT)	-0.0833	0.2292	0.3125

An in-depth rainbow ranking of what makes a smaller varicose vein treatment option preferable or unfavorable is shown in Figure 3.1. Sclerotherapy outperformed endovenous laser treatment (EVLT) with a positive ranking of the cost of treatment, duration of treatment, side effects, and benefits.

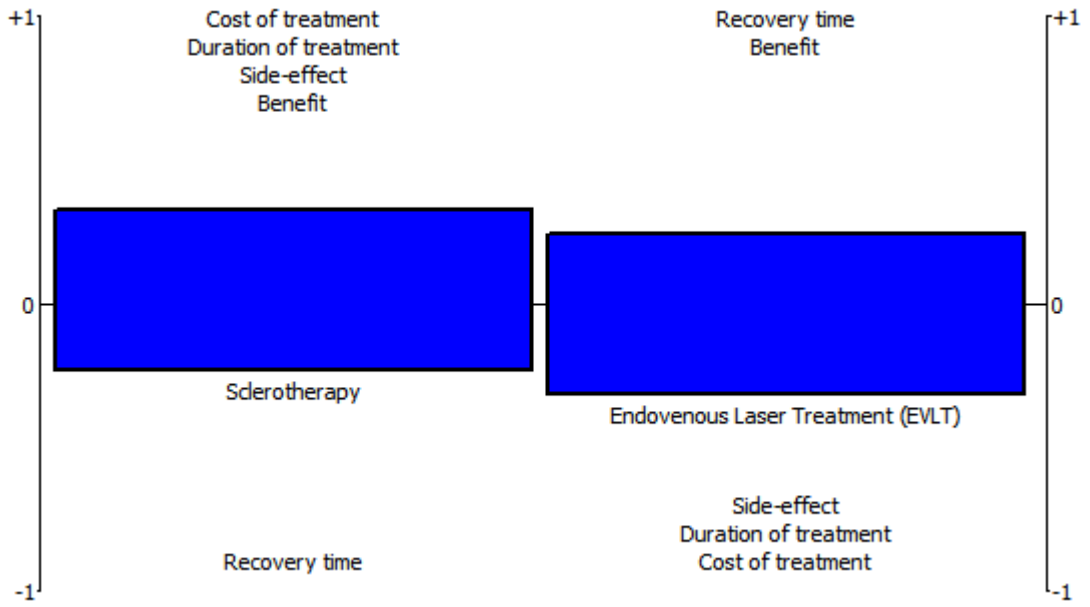

Figure 3.1. Rainbow Ranking for Smaller Varicose Treatment Alternatives

Table 3.2 shows the PROMETHEE result for all alternatives except the cost of treatment for the treatment of smaller varicose veins. This indicates that priority can change based on the patient's or doctor's preference. The cost of treatment may not be a priority when there is adequate funding for the treatment. In this case, Endovenous Laser Treatment (EVLT), with a net outranking flow of 0.1276, is a better alternative for treating a smaller varicose vein.

Table 3.2. PROMETHEE ranking results for smaller varicose treatment alternatives without cost parameter

Rank	Alternative	Phi	Phi+	Phi-
1	Endovenous Laser Treatment (EVLT)	0.1276	0.2819	0.1543
2	Sclerotherapy	-0.1276	0.1543	0.2819

Furthermore, with a positive outranking of 0.4096, a negative outranking flow of 0.0002, and a net outranking flow of 0.4094, EVLT outperformed radiofrequency ablation and surgery in treating larger varicose veins. Surgery with a net outranking flow of 0.3551 is the least favorable treatment alternative for larger varicose veins, as shown in Table 3.3.

Table 3.3. PROMETHEE Ranking Results for Larger Varicose Treatment Alternatives

Rank	Alternative	Phi	Phi+	Phi-
1	Endovenous Laser Treatment (EVLT)	0.4094	0.4096	0.0002
2	Radiofrequency Ablation	-0.0543	0.1778	0.2322
3	Surgery	-0.3551	0.0935	0.4486

Figure 3.2 display the strong and weak point of the alternatives for the treatment of larger varicose vein. It can be seen from the figure that Endovenous Laser Treatment (EVLT) has the strongest points for the cost of treatment, recovery time, duration of treatment, and

side-effect. In contrast, surgery has the lowest point for benefit, side-effect, duration of treatment, and recovery time.

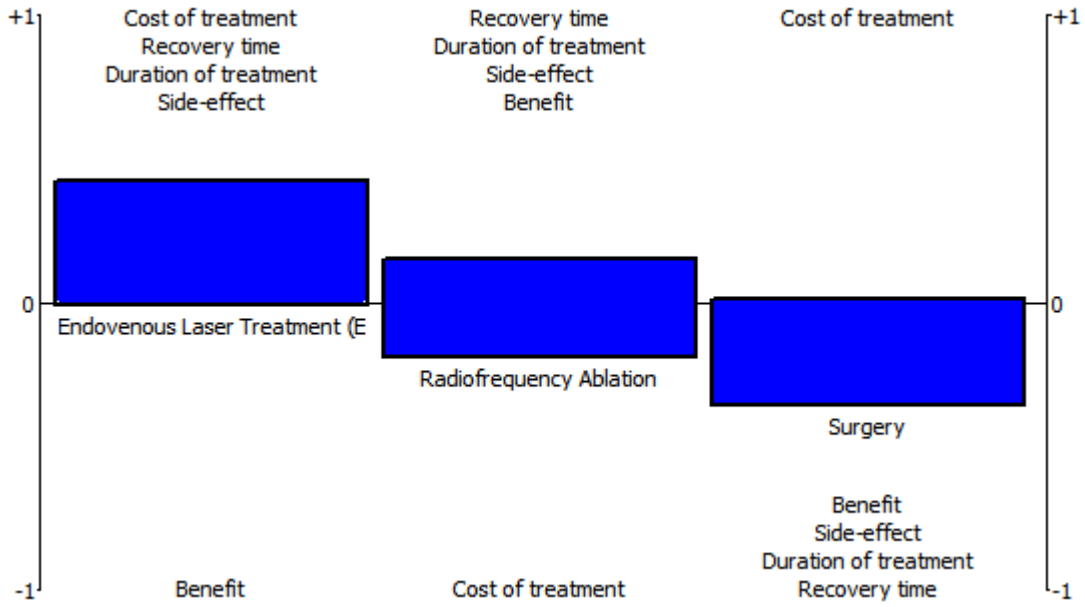

Figure 3.2. Rainbow Ranking for Larger Varicose Treatment Alternatives

Even with the exclusion of the cost of treatment, Endovenous Laser Treatment (EVLT) remains the most favorable alternative. In contrast, surgery remains the least preferred, with a net outranking flow of 0.2736 to treat larger varicose veins, as shown in Table 3.4.

Table 3.4. PROMETHEE ranking results for larger varicose treatment alternatives without cost parameter

Rank	Alternatives	Phi	Phi+	Phi-
1	Endovenous Laser Treatment (EVLT)	0.2736	0.2738	0.0002
2	Radiofrequency Ablation	0.1632	0.2187	0.0555
3	Surgery	-0.4368	0.0000	0.4368

When compared with the PROMETHE, TOPSIS gives a similar result. The Euclidean distance of both smaller and larger varicose veins was then calculated using the ideal best and ideal worst values. The weighted normalized matrix is shown in Tables 3.5 and 3.6.

Table 3.5. The Euclidean distance for smaller varicose treatment alternatives

Alternatives	d^+	d^-
Sclerotherapy	0.2287	0.2293
Endovenous Laser Treatment (EVLT)	0.2293	0.2287

Table 3.6. The Euclidean distance for smaller varicose treatment alternatives

Alternatives	d^+	d^-
Surgery	0.2001	0.0516
Endovenous Laser Treatment (EVLT)	0.0278	0.2094
Radiofrequency Ablation	0.0768	0.1702

Since the benefit values are equal for Sclerotherapy and Endovenous Laser Treatment (EVLT), it is not used as the criteria of the smaller varicose treatment alternatives. We examine which treatment approach is closest to the optimal solution for small varicose veins and rate them accordingly. The score calculated based on the Euclidean distance between the ideal best (Si+) and the ideal worst (Si-) in Table 3.7 is referred to as the performance score. Sclerotherapy rank first as the most preferred treatment alternative with a performance score of 0.5006 for smaller varicose vein. The same method was applied for the larger varicose vein. A performance score of 0.8829 was obtained for Endovenous Laser Treatment (EVLT), outperforming others as the most preferred treatment alternative for larger varicose veins shown in Table 3.8.

Table 3.7. The relative closeness to positive ideal solution (Ri) for smaller varicose treatment alternatives and ranking with TOPSIS

Rank	Alternatives	Ri
1	Sclerotherapy	0.5006
2	Endovenous Laser Treatment (EVLT)	0.4994

Table 3.8. The relative closeness to positive ideal solution (Ri) for larger varicose treatment alternatives and ranking with TOPSIS

Rank	Alternatives	Ri
1	Endovenous Laser Treatment (EVLT)	0.8829
2	Radiofrequency Ablation	0.6892
3	Surgery	0.2049

CHAPTER IV
Discussion

The PROMETHEE analysis of the results shows that sclerotherapy with a net-flow ranking of 0.1605 outclassed other treatment alternatives to treat smaller varicose veins. At the same time, the EVLT is a less preferred alternative. Sclerotherapy has a relatively good ranking in terms of its overall cost, treatment length, side effects, and poor ranking in terms of patient recovery and adverse effects. Subsequently, EVLT outperformed radiofrequency ablation and surgery to emerge as the top choice when treating larger varicose veins. This is evident in the score obtained from its net outranking score of 0.4094. Also, EVLT has a high ranking in cost of treatment, recovery time, duration of treatment, side effects, and low ranking for benefit parameter. Surgery remains the least preferred alternative. Hence, it is the least recommended alternative for treating larger varicose veins.

The resulting outcome for the most preferred alternative for smaller varicose veins changed when the cost parameter was removed. The result indicates that EVLT outperformed sclerotherapy. The change in result proves that criteria selection changes can dramatically alter the result, thereby producing a different result. In addition, if the analysis's weightings change, the treatment options will likely be ranked differently. These findings were based on the consensus of expert opinion, and common occurrences were given a generic weight in this study. Weights can be adjusted based on a patient's preferences and current health status or a doctor's advice.

Fuzzy PROMETHEE is a powerful tool for making decisions in complex settings. There is full control given to the user over the factors and their relative importance and the ability to customize each one to fit their needs. Fuzzy PROMETHEE balances these parameters to come up with a better choice than the other possibilities provided.

The result obtained using the TOPSIS technique is the same as the obtained using the PROMETHEE technique. Sclerotherapy outperformed EVLT as the most preferred alternative for treating smaller varicose veins with a performance score of 0.5006. However, the EVLT technique is the best choice for treating larger varicose veins. EVLT outperformed radiofrequency ablation and surgery with a performance score of 0.8829.

CHAPTER V
Conclusion

To conclude, the purpose of this study is to evaluate treatment alternatives for varicose veins in the leg. When valves in the veins get compromised, varicose veins can develop. Because of this, there is a risk of blood flow issues. An excessive amount of blood builds up in the blood vessels over time. The veins may appear as though they are bulging, twisting, and standing out through the skin. Leg cramps and aches can also be observed in people. And there are various treatment techniques that are used in the treatment of varicose veins. In this study the treatment options of the varicose has been evaluated with multi criteria decision making techniques, specifically fuzzy PROMETHEE and fuzzy TOPSIS.

Varicose vein therapy possibilities abound; however, study showed that preference ranking systems should only be used to assist a professional or decision-maker in making a choice. Varicose vein treatment alternatives may be ranked differently if a person uses a multi-criteria decision-making approach and gives weight to each factor. Both patients and doctors will benefit from this, as a better treatment regimen for varicose veins will be possible. Moreover, even though varicose veins can be painful, others see it as a cosmetic procedure to enhance looks and body aesthetic. It is encouraged to seek a medical solution to the varicose vein whenever it occurs. Also, complications resulting from the varicose vein can be fatal and cause serious pain and change. Hence, patients must constantly identify the vein and seek how it can be solved.

Unfortunately, as has been documented in the literature, no treatment can entirely eliminate the development of varicose veins. However, increasing circulation and muscle tone may help prevent the development of varicose veins or the development of new ones. Besides, the results revealed that through Sclerotherapy, smaller varicose veins could be treated more effectively (Sclerotherapy outperformed EVLT for the treatment of smaller varicose veins with a performance score of 0.5006), and EVLT technique is the best choice for the treatment of larger varicose vein that outperformed radiofrequency ablation and surgery with a performance score of 0.8829. At the end based on the selected parameters and the importance weights.

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