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Does endovenous radiofrequency ablation cause endothermal heat-induced thrombosis?

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ABSTRACT

Objectives: Endovenous radiofrequency ablation (RFA) is widely used for the treatment of chronic venous disease. However, concerns regarding endothermal heat-induced thrombosis (EHIT) have traditionally led to avoidance of ablation close to the saphenofemoral junction (SFJ). This study aimed to evaluate the incidence of EHIT and early anatomic outcomes following flush RFA at the SFJ.

Patients and methods: This single-center retrospective study included 60 limbs treated with endovenous RFA for great saphenous vein incompetence. Patients with CEAP class C2-C6 and no concomitant deep venous insufficiency were included. Ablation was performed using a standardized technique, and limbs were categorized according to flush strategy as optimal flush (+1 to -2 mm) or flush free (>-2 mm). Duplex ultrasonography was performed on postoperative day 1 to assess EHIT and at 1 month to evaluate early anatomic outcome.

Results: No cases of EHIT were detected (0/60; exact 95% confidence interval, 0-5.96%). At 1 month, complete vein occlusion was observed in 41 limbs (68.3%). Complete occlusion was significantly more frequent in the optimal flush group compared with the flush free group (85.4% *vs.* 31.6%; p<0.001). The likelihood of achieving complete occlusion was higher with optimal flush (risk ratio, 2.70; 95% confidence interval, 1.38-5.30). Early anatomic outcomes did not differ between high-risk and low-risk EHIT subgroups.

Conclusion: Flush endovenous RFA at the SFJ appears to be safe in the short term and is not associated with an increased risk of EHIT. Optimal flush positioning is associated with significantly improved early anatomic outcomes.

Keywords: Endovenous radiofrequency ablation, endothermal heat-induced thrombosis, saphenofemoral junction, chronic venous disease, venous reflux.

Endovenous thermal ablation techniques have become the primary treatment modality for chronic venous disease, replacing conventional surgical ligation and stripping in most clinical settings. Among these techniques, endovenous radiofrequency ablation (RFA) is widely adopted due to its reproducibility, favorable safety profile, and consistent occlusion rates. Despite these advantages, thrombotic complications related to endovenous ablation continue to represent a major clinical concern. In particular, endothermal heat-induced thrombosis (EHIT), defined as thrombus extension from the treated superficial vein into the adjacent deep venous system, has been recognized as a distinct and potentially serious complication of thermal ablation procedures. Although EHIT is often detected incidentally on early postoperative duplex ultrasonography, progression to deep vein thrombosis or pulmonary embolism has been reported, underscoring the need for careful procedural planning and surveillance.[1,2]

Concerns regarding EHIT have traditionally influenced technical strategies during RFA, particularly with respect to the saphenofemoral junction (SFJ). To reduce the perceived risk of thrombus propagation into the common femoral vein, many operators have intentionally avoided ablation close to the SFJ, leaving a proximal untreated segment of the great saphenous vein (GSV). However, residual proximal stumps have been associated with persistent reflux, neovascularization, and late recurrence of varicose veins. Several long-term observational studies have suggested that incomplete proximal treatment may compromise

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durable anatomic success, thereby challenging the rationale of routinely avoiding junction-level ablation.[3,4] Reported EHIT rates after endovenous thermal ablation are generally low, but vary across studies and surveillance protocols, with most contemporary RFA series reporting EHIT in the low single-digit percentage range.[5,6]

With improvements in ultrasound guidance, catheter design, and standardized ablation protocols, flush or near-flush ablation at the SFJ has become technically feasible. This approach aims to eliminate the proximal stump while maintaining procedural safety. Nevertheless, the role of flush positioning remains controversial, particularly in patients considered to be at increased risk for EHIT. While several studies have reported low overall EHIT rates following RFA, most series do not specifically stratify outcomes according to flush distance or stump length. Moreover, data evaluating early anatomic outcomes in relation to flush positioning remain limited. As a result, uncertainty persists regarding whether flush ablation at the SFJ meaningfully improves technical success without increasing thrombotic risk.[5]

The present study was designed to evaluate the short-term safety of flush endovenous RFA at the SFJ, with particular emphasis on the occurrence of EHIT. In addition, early anatomic outcomes were compared between different flush strategies to assess whether optimal flush positioning is associated with improved early vein occlusion without compromising safety.

PATIENTS AND METHODS

Study Design and Patient Selection

This single-center retrospective study evaluated patients who underwent endovenous RFA for GSV incompetence between March 2023 and June 2024. All procedures were unilateral; each patient contributed a single treated limb. Limbs were included if patients had chronic venous disease classified as CEAP C2-C6, demonstrated significant reflux at the SFJ on duplex ultrasonography, and had no evidence of concomitant deep venous insufficiency or prior deep vein thrombosis. Limbs with previous venous interventions involving the SFJ or incomplete follow-up were excluded.

Ethical permission was obtained from the Health Sciences Scientific Research Ethics Committee (Kırşehir) for this study with date 17/09/2024 and number 2024-15/127, and Helsinki Declaration rules were followed to conduct this study. Informed consent forms were obtained from all patients.

Definition of EHIT and Risk Stratification

EHIT was defined as thrombus extension from the treated superficial vein into the adjacent deep venous system, detected by duplex ultrasonography. EHIT surveillance and classification were performed in accordance with established consensus definitions. Patients were categorized into low/standard-risk or high-risk EHIT subgroups based on recognized clinical and anatomic risk factors, including vein diameter, body mass index, and disease severity.[1,2] High-risk EHIT status was defined a priori based on recognized risk factors, including vein diameter thresholds (GSV diameter ≥8 mm and/or SFJ diameter ≥10 mm), additional clinical risk factors (e.g., body mass index ≥30 kg/m², advanced CEAP class (4-6), prior venous thromboembolism/thrombophilia), and unfavorable SFJ anatomy on preoperative duplex (e.g., marked junctional ectasia or large accessory confluence). Patients not meeting these criteria were classified as low/standard risk.

Procedural Technique and Flush Categorization

All procedures were performed using a standardized endovenous RFA technique (ClosureFast™, Medtronic), under ultrasound guidance. Venous access was obtained distally, and the ablation catheter was positioned proximally according to the planned flush strategy. Tumescent anesthesia was administered perivenously along the treated segment. Intraoperative ultrasound measurements and catheter positioning were performed by a single experienced operator using a standardized protocol, with the SFJ plane identified in a consistent longitudinal view. Measurements were recorded at the time of catheter positioning and documented in the operative record.

Catheter positioning was planned to achieve an optimal flush when anatomy and ultrasound visualization allowed safe junction-level placement; a flush-free position (>2 mm distal to the SFJ plane) was used when junctional anatomy or accessory confluence limited reliable near-junction positioning. Measurements were referenced to the SFJ plane (the junctional confluence between the GSV and common femoral vein visualized on ultrasound). Distances distal to the SFJ were recorded as negative values, whereas values at or marginally proximal to the SFJ plane (within the superficial junctional segment) were recorded as positive. The 0-PD distance was defined as the ultrasound-measured distance between the proximal end of the post-ablation closure segment (proximal endpoint of the treated/occluded segment) and the SFJ plane. Limbs were categorized into two groups:

- **Optimal flush:** Catheter tip positioned between +1 mm and -2 mm relative to the SFJ,
- **Flush-free:** Catheter tip positioned >2 mm distal to the SFJ plane (i.e., more than -2 mm).

This categorization was selected to reflect clinically relevant differences in proximal stump length while maintaining procedural reproducibility.[5]

Postoperative Surveillance and Follow-up

POD-1 duplex ultrasonography was performed to detect early EHIT at the SFJ and to guide timely management if present. A planned 1-month duplex assessment was used to evaluate early anatomic outcomes and is consistent with guideline-recommended post-ablation surveillance windows (e.g., 1-4 weeks) for clinical and duplex assessment.[1] Early anatomic outcome was categorized as complete occlusion or partial occlusion (mild or moderate residual reflux).[6]

No routine pharmacologic prophylaxis (UFH/LMWH) was administered solely based on EHIT risk category; anticoagulation was reserved for patients with an established indication. This is stated to facilitate interpretation of thrombotic outcomes.

Study Endpoints

The primary endpoint of the study was the occurrence of EHIT within the early postoperative period. Secondary endpoints included early anatomic outcome at 1 month and comparison of occlusion patterns according to flush strategy and EHIT risk subgroup.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation, and categorical variables as counts and percentages. Baseline characteristics were compared between flush groups using the Wilcoxon rank-sum test for continuous variables and Fisher's exact test for categorical variables. The incidence of EHIT was reported descriptively with exact 95% confidence intervals. Associations between flush strategy and early anatomic outcome were evaluated using Fisher's exact test, and effect size was expressed as risk ratios with corresponding confidence intervals. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

Study Population and Baseline Characteristics

A total of 60 patients (60 treated limbs) were included in the analysis; all procedures were unilateral. The mean patient age was 47.1±14.8 years, and the mean body mass index was 28.3±4.0 kg/m². The mean GSV diameter was 7.1±1.6 mm. Female patients constituted 58.3% of the cohort, and diabetes mellitus was present in 46.7% of patients.

According to CEAP classification, 36 limbs (60.0%) were classified as C2-C3 and 24 limbs (40.0%) as C4-C6. Overall, 26 limbs (43.3%) were categorized as high risk for EHIT.

Based on proximal catheter positioning, 41 limbs (68.3%) were treated using an optimal flush strategy, while 19 limbs (31.7%) were treated using a flush free strategy.

Baseline demographic, clinical, and anatomic characteristics were comparable between the two flush groups. No statistically significant differences were observed with respect to age, body mass index, GSV diameter, sex distribution, diabetes mellitus, CEAP class distribution, or EHIT risk category (all p>0.05) (Table 1).

Procedural Characteristics and Early Follow-up

All procedures were completed successfully using a standardized RFA protocol. Flush positioning was achieved according to the predefined intraoperative ultrasound measurements, allowing clear separation between optimal flush and flush free groups (Figure 1).

All patients underwent duplex ultrasonography on postoperative day 1. No cases of deep vein thrombosis were detected during early postoperative surveillance. A follow-up duplex examination was completed at 1 month in all included limbs, allowing assessment of early anatomic outcomes.

Primary Outcome: EHIT

No cases of EHIT were detected during the early postoperative period. EHIT incidence was 0 of 60 treated limbs, corresponding to an estimated incidence of 0%, with an exact 95% confidence interval ranging from 0% to 5.96%. No cases of deep vein thrombosis were observed on postoperative day 1 or during the 1-month follow-up period.

Secondary Outcome: Early Anatomic Results at 1 Month

At 1-month follow-up, complete occlusion of the treated GSV was observed in 41 of 60 limbs (68.3%). Partial occlusion, defined as the presence of mild or moderate residual reflux, was identified in 19 limbs (31.7%).

When stratified by flush strategy, complete occlusion was significantly more frequent in the optimal flush group than in the flush free group. In the optimal flush group, 35 of 41 limbs (85.4%) demonstrated complete occlusion, compared with 6 of 19 limbs (31.6%) in the flush free group. This difference was statistically significant (Fisher's exact test, p<0.001).

The likelihood of achieving complete occlusion was significantly higher in limbs treated with an optimal flush strategy, with a risk ratio of 2.70 (95% confidence interval, 1.38-5.30).

Table 1. Baseline characteristics of the study cohort according to flush strategy

Characteristics	Overall (n=60)	Optimal flush (+1 to -2 mm) (n=41)	Flush free (>-2 mm) (n=19)	p-value
Age, years	47.1±14.8	47.6±14.7	46.1±15.5	0.7205
BMI, kg/m²	28.3±4.0	28.1±3.7	28.5±4.6	0.8737
GSV diameter, mm	7.1±1.6	7.0±1.8	7.4±1.3	0.1020
Sex, n (%)				0.5831
Female	35 (58.3%)	25 (61.0%)	10 (52.6%)	
Male	25 (41.7%)	16 (39.0%)	9 (47.4%)	
Diabetes mellitus, n (%)	28 (46.7%)	20 (48.8%)	8 (42.1%)	0.7821
CEAP class, n (%)				0.3431
C2-C3	36 (60.0%)	27 (65.9%)	9 (47.4%)	
C4-C6	24 (40.0%)	14 (34.1%)	10 (52.6%)	
High-risk EHIT subgroup, n (%)				1.0000
Low/standard risk	34 (56.7%)	23 (56.1%)	11 (57.9%)	
High risk	26 (43.3%)	18 (43.9%)	8 (42.1%)	

BMI: Body mass index; GSV: Great saphenous vein; EHIT: Endothermal heat-induced thrombosis.

Subgroup Analysis: EHIT Risk Stratification

Early anatomic outcomes were further analyzed according to EHIT risk stratification. No statistically significant difference in complete occlusion rates was observed between limbs categorized as high risk and those categorized as low or standard risk for EHIT. Similarly, EHIT did not occur in either risk subgroup.

Summary of Results

Across the entire cohort, flush endovenous RFA at the SFJ was not associated with the occurrence of EHIT. Optimal flush positioning was associated with a significantly higher rate of early complete vein occlusion, without an increase in thrombotic complications (Figure 2).

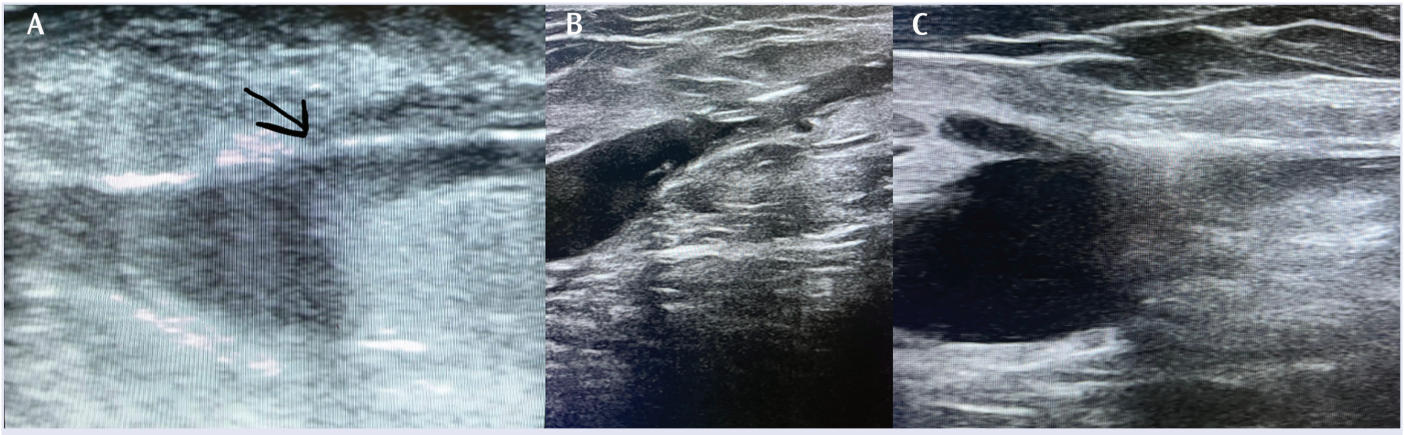

Figure 1. Intraoperative catheter positioning and postoperative saphenofemoral junction imaging. (**A**) Intraoperative ultrasound image demonstrating proximal positioning of the radiofrequency ablation catheter at the saphenofemoral junction (arrow). (**B**) Postoperative duplex ultrasonography image of the saphenofemoral junction showing a 0-PD distance of -5 mm, consistent with a flush-free ablation strategy. (**C**) Postoperative duplex ultrasonography image of the saphenofemoral junction showing a 0-PD distance of -1 mm, consistent with an optimal flush ablation strategy.

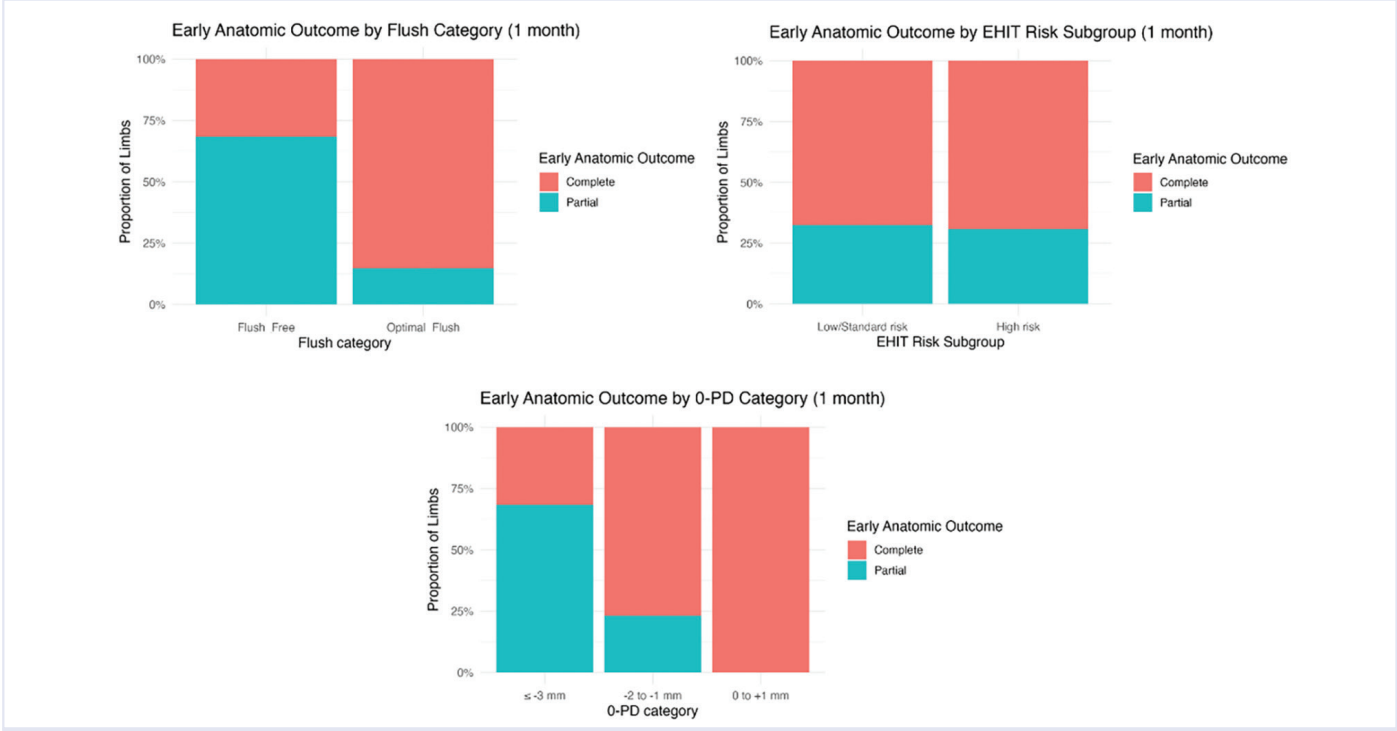

Figure 2. Early anatomic outcomes according to flush strategy, 0-PD distance, and EHIT risk subgroup. Stacked bar plots illustrate early anatomic outcomes at 1 month following endovenous radiofrequency ablation. Early anatomic outcomes stratified by flush strategy, comparing Optimal_Flush and Flush_Free positioning. Early anatomic outcomes stratified by 0-PD distance category (≤-3 mm, -2 to -1 mm, and 0 to +1 mm). Early anatomic outcomes stratified by EHIT risk subgroup (low/standard risk *vs.* high risk). Early anatomic outcome was classified as complete occlusion or partial occlusion (mild or moderate residual reflux). Bar heights represent proportions within each subgroup.
EHIT: Endothermal heat-induced thrombosis.

DISCUSSION

The present study demonstrates that flush endovenous RFA at the SFJ can be performed safely in the short term, without an increased risk of EHIT. In a cohort that included a substantial proportion of patients categorized as high risk for EHIT, no cases of EHIT were detected, and early anatomic outcomes were significantly improved with optimal flush positioning.

Published EHIT rates after RFA vary, with contemporary large-scale series typically reporting overall EHIT in the low single-digit range and severe EHIT being uncommon; therefore, our observed EHIT incidence of 0/60 should be interpreted within the context of limited sample size and the corresponding exact confidence interval.[1,5]

Concerns regarding EHIT have historically shaped technical strategies during endovenous thermal ablation, particularly at the level of the SFJ. EHIT has been recognized as a distinct complication of thermal ablation, characterized by thrombus extension into the deep venous system, with variable clinical significance depending on the degree of extension. Although most EHIT cases are detected incidentally and remain clinically silent, progression to deep vein thrombosis and pulmonary embolism has been reported, reinforcing a conservative approach in junction-level treatment.[1,2]

As a result, many operators have traditionally avoided ablation close to the SFJ, intentionally leaving a proximal untreated segment of the GSV. However, the presence of a residual proximal stump has been implicated in persistent reflux and late recurrence. Long-term surgical and endovenous series have suggested that incomplete proximal treatment may compromise durable anatomic success, challenging the rationale of routinely avoiding the junction.[3,4]

With advances in ultrasound guidance and standardized ablation techniques, flush or near-flush ablation at the SFJ has become technically feasible. Nevertheless, data specifically addressing the safety of flush positioning in relation to EHIT remain limited. Most published RFA series report overall EHIT rates but do not stratify outcomes according to catheter position or stump length. In this context, the absence of EHIT in the present cohort, despite intentional flush positioning and inclusion of high-risk patients, provides supportive evidence that flush RFA at the SFJ does not inherently increase thrombotic risk when performed with careful technique and appropriate surveillance.[5]

Beyond safety, the present study highlights a clinically relevant association between flush strategy and early anatomic outcome. Optimal flush positioning was associated with a significantly higher rate of complete vein occlusion at 1 month, with a nearly threefold increase in the likelihood of achieving complete occlusion compared with a flush-free approach. Importantly, baseline characteristics were comparable between groups, suggesting that this difference reflects a technical effect rather than selection bias. These findings support the concept that minimizing the proximal stump may enhance early technical success without compromising safety. Early complete occlusion at 1 month represents an anatomic surrogate endpoint. The present study did not evaluate symptom scores, venous severity measures, or quality-of-life outcomes, and the short follow-up precludes conclusions regarding long-term durability, recurrence, or clinical benefit. Therefore, the observed association between optimal flush positioning and early occlusion should not be overinterpreted as evidence of improved long-term clinical outcomes.

Subgroup analysis further demonstrated that EHIT risk stratification did not influence early anatomic outcomes, and EHIT did not occur in either risk category. Although the study was not powered to detect rare thrombotic events, this observation suggests that flush positioning may be feasible even in patients considered at increased risk for EHIT, provided that meticulous technique and early duplex surveillance are employed.

Several limitations of this study should be acknowledged. The retrospective design and single-center setting may limit generalizability. Although no EHIT events were observed, the sample size limits our ability to detect rare complications; therefore, low-frequency EHIT events cannot be excluded, as reflected by the exact 95% confidence interval. Nevertheless, the use of standardized procedural techniques, objective duplex-based assessment, and clearly defined flush categories strengthens the internal validity of the findings. Residual tumescent fluid in the early postoperative period may reduce image quality and could potentially influence fine measurements around the junction. Nevertheless, EHIT assessment primarily relied on evaluation of thrombus extension into the deep venous lumen at the SFJ, and all studies were performed by experienced sonographers; this remains a potential limitation. This EHIT risk categorization was a pragmatic, center-based operational definition rather than a formally validated prediction model, which may limit comparability across studies. The observed diabetes prevalence reflects the routine case-mix treated at our center during the study period and was not the result of targeted selection. Laboratory markers related to thrombosis surveillance (e.g., D-dimer) were not routinely collected in this retrospective cohort and therefore could not be analyzed; this represents another limitation. Flush categorization relied on precise millimetric ultrasound measurements and may be operator-dependent. Interobserver variability was not formally assessed; therefore, measurement error around narrow cut-offs could influence group assignment and may limit generalizability.

In conclusion, flush endovenous RFA at the SFJ appears to be safe in the short term and is not associated with an increased risk of EHIT. Optimal flush positioning is associated with significantly improved early anatomic outcomes. Further prospective studies with larger cohorts and longer follow-up are warranted to confirm these findings and to clarify the long-term clinical implications of flush ablation strategies.

Flush endovenous RFA at the SFJ was not associated with EHIT in this cohort; however, given the sample size, rare EHIT events cannot be excluded and the findings should be interpreted with caution. In this study, no EHIT events were observed despite the inclusion of patients with recognized risk factors. Optimal flush positioning was associated with significantly improved early anatomic outcomes, as reflected by higher rates of complete vein occlusion. These findings support the feasibility of flush ablation strategies at the SFJ when performed with careful technique and early duplex surveillance. Further prospective studies with larger patient cohorts and longer follow-up are needed to define the long-term clinical implications of this approach.

Ethics

Ethics Committee Approval: Ethical permission was obtained from the Health Sciences Scientific Research Ethics Committee (Kırşehir) for this study with date 17/09/2024 and number 2024-15/127, and Helsinki Declaration rules were followed to conduct this study.

Informed Consent: Informed consent forms were obtained from all patients.

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Footnotes

This study has been accepted for an oral presentation at the 18th Congress of the Turkish Society of Cardiovascular Surgery, to be held in Antalya on November 21, 2024.

Authorship Contributions

Surgical and Medical Practices: İ.D., İ.S.K.; Concept: İ.D.; Design: İ.D., M.A.K.; Data Collection or Processing: İ.D., İ.S.K.; Analysis or Interpretation: İ.D., M.A.K.; Literature Search: İ.S.K., M.A.K.; Writing: İ.D., M.A.K., İ.S.K.

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