Ultrasound-Guided Peripheral Intravenous Catheterization in Patients With Difficult Venous Access: A Comparative Study of Antecubital Versus Saphenous Veins

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Abstract- Establishing reliable intravenous access in patients with difficult peripheral veins is a common challenge in perioperative care. In such cases, central venous catheterization (CVC) is often used despite its invasive nature and associated risks. For short elective procedures, this may be excessive. Ultrasound-guided peripheral vein catheterization (US-PVC) has emerged as a safer, less invasive alternative that improves success rates. However, limited evidence exists comparing different anatomical sites for US-PVC in this population. This study aims to compare the efficacy and complication rates of ultrasound guided IV access in the antecubital versus saphenous regions in adult surgical patients with difficult venous access. This single-center, parallel-group, randomized clinical trial was conducted on adult patients undergoing elective surgery with difficult peripheral venous access. Patients were randomized to receive US-guided catheterization in either the antecubital (Group A) or saphenous (Group B) region. All procedures were performed by an anesthesiologist experienced in ultrasound-guided vascular access. Primary outcomes included first-attempt success rate and catheterization time; secondary outcomes included complication rates and patient-reported satisfaction. Follow-up assessments were conducted at 24 hours and 72 hours post-procedure. The saphenous group demonstrated significantly higher first-attempt success rates (53.1% vs. 44.9%, P=0.04) and greater catheter durability (89.8% vs. 75.6%, P=0.03). However, this group also reported significantly more procedural pain based on VAS scores (4.94 vs. 2.24, P<0.001), as well as greater increases in mean arterial pressure and heart rate. Although complication rates such as hematoma and thrombophlebitis were slightly higher in the antecubital group, the differences were not statistically significant. Patient satisfaction was significantly higher in the saphenous group (95.8% vs. 77.6%, P=0.001), while staff satisfaction did not differ meaningfully between groups. Ultrasound-guided IV catheterization in both antecubital and saphenous regions is effective in patients with difficult venous access. The saphenous site offers higher first-attempt success and catheter longevity but is associated with more discomfort. These findings may aid anesthesiologists in selecting optimal access sites based on clinical needs and patient tolerance. This study was approved by the Tehran University of Medical Sciences Ethics Committee (Ethics Code: IR.TUMS.IKHC.REC.1402.418, IRCT Id: IRCT20230130057273N2).

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Introduction

Peripheral vein catheterization (PVC) is a fundamental component of modern perioperative and inpatient care, with over 80% of hospitalized patients requiring intravenous access for fluid administration, medications, blood sampling, or transfusion (1). In many patients, especially those with obesity, chronic illness, or poor vascular anatomy, achieving reliable IV access using conventional palpation or visualization methods proves difficult, resulting in delayed treatment, multiple failed attempts, and increased patient discomfort (2,3).

As anesthesiologists working in the operating room, we frequently encounter patients referred to for elective surgeries who arrive without viable peripheral IV access. In such scenarios, central venous catheterization (CVC) is often employed as a fallback option. However, CVC is inherently invasive and introduces avoidable risks, such as bloodstream infection, arterial injury, pneumothorax, and thrombosis (4,5), particularly in low-risk surgical candidates who are expected to be hospitalized for only a short period. For these patients, the placement of a central line purely due to failure of peripheral access represents a disproportionate escalation in invasiveness, cost, and complication risk.

Ultrasound-guided peripheral vein catheterization (US-PVC) offers a safe and effective alternative in patients with difficult venous access (DVA). Numerous studies have demonstrated that US guidance improves the success rate of peripheral IV placement, reduces the number of cannulation attempts, shortens procedural time, and enhances patient satisfaction compared to traditional landmark-based methods (6-8). US-guided catheterization has also proven especially beneficial in emergency and perioperative settings, even when performed by trained non-physician personnel such as ED technicians (9). Moreover, US-PVC is less invasive, more cost-effective, and associated with fewer complications than central venous catheterization, especially in short-stay surgical patients (10).

Among peripheral access sites, upper limb veins—especially those in the antecubital fossa—are the traditional first-line targets. However, lower limb veins, such as the great saphenous vein near the medial malleolus, can serve as viable alternatives in certain clinical contexts, particularly when upper limb access is limited or previously exhausted (11-13).

Despite the increasing use of US guidance in IV access, limited data exists comparing the efficacy, efficiency, and safety of catheterization at different anatomical sites. Most studies focus on a single site, and few offer direct comparisons to guide decision-making in real-time clinical settings. Therefore, we designed this randomized clinical study to compare ultrasound-guided IV access between two commonly used regions—the antecubital and the saphenous—in adult surgical patients with difficult peripheral access.

This study aims to evaluate first-attempt success rate, cannulation time, short-term complications, and patient-reported outcomes across these two sites. Our findings seek to inform us of a more practical, efficient, and patient-centered approach to vascular access, especially for anesthesiologists managing acute cases where minimizing invasiveness is critical.

Materials and Methods

Study design and participants:

This single-center, parallel-group randomized clinical trial was approved by the Tehran University of Medical Sciences Ethics Committee (Ethics Code: IR.TUMS.IKHC.REC.1402.418). All participants were fully informed about the study, and written consent was obtained. The trial was conducted in 2024 at Imam Khomeini Hospital, Tehran, Iran. The sample size was calculated using Witting's equation ($N=z2\ p(1-p)/d2$ where $z2=1.96$, $P=0.56$, $d=0.14$) (14), resulting in 49 patients per group (n=49), for a total study population of 98 patients (n=98).

Inclusion criteria included adults aged 18 to 65 years who were candidates for elective surgery with an anticipated hospital stay of three days or less, had difficult peripheral venous access (defined as visible or palpable veins deemed unsuitable for cannulation upon first inspection by the attending anesthesiologist), and provided written informed consent. Exclusion criteria included age <18 or >65 years, American Society of Anesthesiologists (ASA) classification >2, emergent surgical requirements, coagulopathies, cardiovascular diseases, infections, chronic kidney disease (CKD), diabetes, immune deficiencies, anticipated surgical duration >3 hours, psychotic or cognitive impairments, mental retardation, history of smoking or substance abuse, high risk of significant intraoperative bleeding, and systolic blood pressure <90 mmHg or >160 mmHg.

Randomization and blinding

Patients were allocated using a computer-generated block randomization scheme (block size=4) to one of two groups: ultrasound-guided catheterization via either the

antecubital or saphenous vein. Allocation concealment was ensured using sealed opaque envelopes. While procedural personnel were not blinded due to the nature of the intervention, outcome assessors recording satisfaction scores and complications were blinded to group allocation.

Procedure

At the beginning of the procedure, baseline demographic data (age, gender, body mass index [BMI]) and hemodynamic parameters, including mean arterial pressure (MAP) and heart rate, were recorded by the attending anesthesiologist. Patients were positioned in the supine position and monitored according to ASA standards. Those with ASA classification ≤2 was randomized into either the antecubital or saphenous group (n=49 per group) using a block randomization method.

Venous access was attempted on the non-dominant limb in both groups, with a tourniquet applied to facilitate venous congestion. After aseptic skin preparation with betadine, a sterile-covered linear ultrasound probe (6-13 MHz frequency, 1-3 cm depth) was used to locate a suitable vein. In the antecubital group, the basilic, cephalic, brachial, and medial cubital veins were evaluated in the short-axis view using sliding probe movements (distal-to-proximal and medial-to-lateral). The most superficial vein with an anteroposterior diameter ≥3 mm was selected.

In the saphenous group, ultrasound evaluation of the saphenous vein was performed on the supero-anterior medial ankle, sliding the probe proximally-to-distally and medially-to-laterally. Compressibility testing and Doppler ultrasonography were used to confirm vein patency.

The probe was positioned over the site where the selected vein was closest to the skin. A 20-gauge angiocath (B. Braun) was inserted at a 10-40° angle approximately 0.5-1 cm from the probe, aligned with the identified vein. Insertion was guided in real-time by observing tissue movement on the ultrasound screen. Upon blood return in the flash chamber, the needle was advanced 1-2 mm, the mandrin removed, and the catheter secured.

Ultrasound imaging in both long- and short-axis views, along with Doppler visualization during a 3 mL saline flush, confirmed catheter placement. The procedure end time and post-procedural hemodynamic parameters were then recorded.

If certain predefined complications occurred (e.g., inability to identify a suitable vein ≥3 mm, subcutaneous hematoma formation, misplacement of catheter, extravasation, or ≥3 failed attempts), the access site was changed. If similar issues occurred again, the patient was excluded from the study.

All procedures were performed by an experienced anesthesiologist trained in ultrasound-guided peripheral venous catheterization.

Outcome measures

Primary outcome measures included:

-First-attempt success rate.

-Duration of the procedure, measured from ultrasound probe placement to successful catheter fixation.

Secondary outcome measures included:

-Number of attempts required for successful cannulation.

-Procedural pain (measured via VAS).

-Hemodynamic changes (MAP and HR) pre- and post-cannulation.

-Occurrence of complications: hematoma, thrombophlebitis, and extravasation (evaluated up to 72 hours post-procedure).

-Patient and staff satisfaction at 24 hours.

Assessment tools

-Pain was assessed immediately after cannulation using the Visual Analog Scale (VAS), a 10 cm horizontal line representing pain intensity from 0 (no pain) to 10 (worst pain imaginable).

-Hemodynamic parameters (MAP and HR) were recorded before and after the procedure.

-Catheter durability was determined by confirming patency and functionality for intravenous therapy without complications for 72 hours post-insertion.

-Complications (hematoma, thrombophlebitis, and extravasation) were monitored and documented through clinical evaluation by blinded assessors up to three days post-procedure.

-Patient satisfaction was assessed 24 hours post-procedure based on the patient's subjective report of comfort and absence of limitations in routine activities. Although no standardized questionnaire was used, responses were documented through a structured clinical interview by a blind investigator.

-Staff satisfaction was assessed by evaluating continued vein patency and effective drug administration during the same 24-hour period using a structured Likert-scale format.

Statistical analysis

Data was analyzed using SPSS version [IBM Corp.,

version 25]. Continuous variables were expressed as mean±SD and compared using independent t-tests or Mann-Whitney U-tests. Categorical variables were analyzed using Chi-square or Fisher's exact tests. A $P<0.05$ was considered statistically significant.

Results

In this study, 98 subjects were enrolled and randomly assigned to either the antecubital or saphenous group. The mean age in the antecubital group was 59.86 years, while in the saphenous group it was 58.94 years. The difference between the two groups was not statistically significant ($P=0.3$), confirming that randomization and patient distribution were appropriate. In the antecubital group, 55.1% of patients were male, whereas in the saphenous group, 59.2% were female. This difference was also not statistically significant, indicating that the groups were comparable in terms of gender distribution. Further demographic data can be found in Table 1.

Table 1. Demographic data comparison between the two groups

	Antecubital group	Saphenous group	*P*
Age (mean±SD)	59.86±15.94	58.94±16.01	0.3
Gender (percentage)	Male (55.1%)	Female (59.2%)	0.2
BMI (mean±SD)	27.46±4.04	26.16±3.59	0.2

The first attempt success rate was 44.9% in the antecubital group compared to 53.1% in the saphenous group. The difference in total insertion attempts between the two groups was statistically significant ($P=0.04$). The mean procedure time was 4.88 minutes in the antecubital group and 5.16 minutes in the saphenous group. The catheter durability was higher in the saphenous group (89.8%) compared to the antecubital group (75.6%), with this difference also being statistically significant ($P=0.03$).

Regarding pain perception, as measured by the Visual Analog Scale (VAS), the antecubital group reported a mean score of 2.24, while the saphenous group reported a significantly higher mean score of 4.94 ($P=0.001$), indicating more severe pain during the procedure. The increase in mean arterial pressure during the procedure was also statistically significant between the groups (antecubital group: 10.49 mmHg vs saphenous group: 12.20 mmHg, $P=0.001$). Similarly, the change in heart rate was significantly higher in the saphenous group (6.22 bpm) compared to the antecubital group (3.49 bpm), with a P of 0.001.

In terms of procedural complications, extravasation occurred only in the antecubital group (8.2%) and was not observed in the saphenous group, although this difference was not statistically significant ($P=0.19$). The incidence of hematoma during needle insertion was low in both groups (antecubital group: 10.3% vs saphenous group: 4.1%). The occurrence of thrombophlebitis was also low, with a 2.1% incidence in the antecubital group and 4.1% in the saphenous group.

Patient satisfaction 24 hours after the procedure was higher in the saphenous group (95.8%) compared to the antecubital group (77.6%), and this difference was statistically significant ($P=0.001$). However, nurse satisfaction scores did not show a significant difference between the two groups (antecubital group: 75.6% vs saphenous group: 89.7%, *P=0.1*).

Further detailed information is provided in Table 2 and 3.

Table 2. Frequency of number of catheterization attempts required in each group for successful catheterization

	Antecubital group	Saphenous group
1 attempt (percentage)	22 (44.9%)	26 (53.1%)
2 attempts (percentage)	19 (38.8%)	13 (26.5%)
3 attempts (percentage)	8 (16.3%)	10 (20.4%)

$P=0.04$*

Table 3. Frequency of possible complications during or 3 days after catheterization

	Antecubital group	Saphenous group	*P*
Extravasation (percentage)	4 (8.2%)	0 (0%)	0.19
Hematoma (percentage)	5 (10.3%)	2 (4.1%)	0.2
Thrombophlebitis (percentage)	1 (2.1%)	2 (4.1%)	0.6

Discussion

This study explored the comparative efficacy and clinical implications of ultrasound-guided peripheral vein catheterization in two anatomical regions—antecubital and saphenous—among patients with difficult peripheral venous access. Our findings support the role of ultrasound guidance in optimizing vascular access and minimizing the need for central venous catheterization in elective surgical candidates with anticipated short hospital stays.

The use of ultrasound for peripheral venous access has consistently been associated with improved first-attempt success rates and lower complication profiles, particularly in patients with non-visible or non-palpable veins (10,15). These advantages become particularly salient in clinical contexts where timely cannulation is necessary, and traditional blind techniques are less effective or prone to failure (6).

Catheter insertion success and durability

In our randomized trial, the saphenous group demonstrated a significantly higher first-attempt success rate compared to the antecubital group (53% vs. 44%, *P*=0.04), aligning with findings from Soltz *et al*., and Triffere *et al*., who reported superior access outcomes in the lower extremity under ultrasound guidance (16,17). While Triffere's high success rates were influenced by pediatric anesthesia, our results extend this observation to awake adult populations.

Anatomical factors such as vein depth and diameter substantially influence access success. Witting et al. and Fields *et al*., observed that superficial veins with diameters ≥0.4 cm are more amenable to successful cannulation, particularly in upper extremity sites (14). Our findings reinforce this principle, while also highlighting the stability advantage of lower extremity veins, as reflected in the saphenous group's superior catheter survival (90% vs. 75%). This observation is consistent with Vinograd *et al*., who reported a 25% failure rate for long-term peripheral catheters (18).

A potential explanation for this disparity in catheter durability lies in the biomechanical activity of the access site. Upper limbs are subject to greater movement during hospitalization, increasing the risk of catheter dislodgment. Conversely, the immobilization of lower limbs may contribute to longer catheter survival.

Procedural efficiency

Despite a slightly shorter mean procedure time in the antecubital group, the difference was not statistically significant. The lack of consensus in the literature regarding time measurement standards (e.g., from patient selection (19) vs. tourniquet application (20)) complicates direct comparisons. In our study, time was measured from ultrasound probe application, providing a clinically relevant marker for evaluating efficiency.

Patient-centered outcomes and satisfaction

Pain scores were significantly higher in the saphenous group (4.9±0.81) than in the antecubital group (2.2±1.58), possibly reflecting differences in sensory innervation and tissue density. This finding contrasts with earlier studies by Duran *et al*., and Tran *et al*., which found no significant difference in pain between traditional and ultrasound-guided techniques (21,22).

Interestingly, despite experiencing higher pain scores, patients in the saphenous group reported significantly greater satisfaction (95% vs. 77%). This paradoxical finding may be attributed to higher first-attempt success rates and improved catheter longevity, which likely outweighed the discomfort associated with cannulation. More pronounced hemodynamic changes in this group further suggest that pain perception varies depending on anatomical site; however, no clinically significant adverse effects were observed.

While prior studies such as the meta-analysis by Tran *et al*., (22) have shown improved satisfaction with ultrasound-guided techniques compared to traditional methods, it is important to note that our study compared two different ultrasound-guided access sites. Thus, our findings suggest that factors such as cannulation success and catheter stability may play a more critical role in

shaping patient satisfaction than pain perception alone. Additionally, nurse satisfaction was higher in the saphenous group (89% vs. 75%), consistent with earlier research by Devis and Quincy, which highlighted the positive impact of ultrasound training on procedural outcomes (23,24).

Safety and complications

Both access sites demonstrated low complication rates, reaffirming the safety of ultrasound-guided catheterization. No nerve or arterial punctures were observed, and the incidences of hematoma, thrombophlebitis, and extravasation were low and comparable. These findings are consistent with prior literature, including studies by Duran, Vinograd, and Tran (18,21,22).

However, Chen *et al.,'s* meta-analysis suggested a higher rate of phlebitis and thrombosis in lower extremity catheterization, though no significant differences were noted in infection or mechanical obstruction rates (25). This discrepancy may stem from variations in patient populations, insertion protocols, and follow-up durations across studies.

Taken together, our findings confirm that ultrasound-guided peripheral vein catheterization is a safe, effective, and patient-preferred technique for vascular access. The saphenous approach offers higher success and durability but comes with greater discomfort. Clinical decision-making should therefore balance procedural efficiency, patient experience, anatomical feasibility, and the provider's skill set. Further studies are warranted to guide tailored site selection and optimize outcomes across diverse patient groups.

Limitations

One important limitation of this study is the definition of difficult venous access (DVA), which was based on clinical judgment by the attending anesthesiologist, defined as the presence of visible or palpable veins deemed unsuitable for cannulation. Although this approach reflects routine clinical practice and has been used in prior studies, it is inherently subjective and may introduce inter-operator variability. The absence of a standardized or validated scoring system for DVA may limit the reproducibility and generalizability of our findings. Future studies would benefit from incorporating objective or validated DVA assessment tools to improve consistency across operators and clinical settings. Another limitation relates to the assessment of patient and staff satisfaction. Satisfaction outcomes were evaluated using structured clinical interviews rather than validated questionnaires. While this method allowed practical and timely data collection in the perioperative setting, it may introduce measurement bias and reduce the precision of satisfaction-related outcomes. Therefore, these results should be interpreted with caution. Future research should consider the use of validated satisfaction instruments to enhance the reliability and comparability of patient- and staff-reported outcomes. Finally, this study was conducted at a single center, and all procedures were performed by an experienced anesthesiologist, which may limit the external validity of the results. Outcomes may differ in other institutions or when performed by providers with varying levels of ultrasound experience. Multicenter studies with diverse operator backgrounds are warranted to further validate these findings.

This randomized controlled trial demonstrated that ultrasound-guided peripheral vein catheterization in the saphenous region offers higher first-attempt success and greater catheter durability compared to the antecubital region in patients with difficult peripheral venous access. Despite being associated with higher pain perception and more pronounced hemodynamic changes, the saphenous approach resulted in significantly greater patient satisfaction—likely due to its procedural reliability and lower failure rate. Both access sites demonstrated low complication rates and high levels of nurse satisfaction, underscoring the overall safety and feasibility of ultrasound-guided peripheral access. These findings support the consideration of the saphenous site as a valuable alternative in clinical situations where upper extremity access is challenging or previously unsuccessful. Further multicenter trials are recommended to validate these findings across diverse patient populations and procedural settings.

This single-center, parallel-group randomized clinical trial was approved by the Tehran University of Medical Sciences Ethics Committee (Ethics Code: IR.TUMS.IKHC.REC.1402.418). All participants were fully informed about the study, and written consent was obtained. This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

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