

Ultrasound-Guided versus Fluoroscopy-Guided Femoral Access for Structural Heart Procedures: Outcomes From Transcatheter Aortic Valve Implantation and Left Atrial Appendage Closure

ABSTRACT

Background: Transfemoral access is the default approach for transcatheter aortic valve implantation (TAVI) and left atrial appendage closure (LAAC). Although ultrasound (US)-guided femoral puncture improves first-pass success and reduces vascular complications in randomized trials, real-world data in contemporary structural heart interventions, including both arterial and venous large-sheath access, remain limited. The authors aimed to compare US-guided vs. conventional transfemoral access in patients undergoing TAVI and LAAC.

Methods: This single-center, retrospective cohort study included 165 consecutive patients undergoing transfemoral structural procedures between January 2022 and December 2024 (93: TAVI; 72: LAAC). Ultrasound guidance was used in 57 procedures (34.5%). Arterial and venous cohorts were analyzed separately. Primary outcomes were absolute hemoglobin decrease (Δ Hb) and access-site vascular complications (hematoma, pseudoaneurysm, and arteriovenous fistula). In the arterial cohort, 1:1 propensity score matching was performed to adjust for baseline differences.

Results: Hemoglobin decline was significantly smaller with US guidance in both venous (0.80 ± 0.95 vs. 1.50 ± 1.11 g/dL; $P = .009$) and arterial procedures (0.58 ± 0.97 vs. 1.29 ± 1.00 g/dL; $P = .002$). In the venous cohort, complication rates were numerically lower but not statistically different (3.8% vs. 17.4%; $P = .143$). In contrast, arterial complications were significantly reduced with US guidance. After propensity matching (31 patients per group), complications occurred in 3.2% vs. 29.0% [Absolute Risk Reduction (ARR) = 25.8%, Number Need to Treat (NNT) = 4, $P = .013$].

Conclusions: Ultrasound-guided transfemoral access was associated with reduced hemoglobin decline and fewer vascular complications, particularly in large-bore arterial procedures, supporting routine integration of real-time US guidance in structural interventions.

Keywords: Complications, fistula, imaging, interventional cardiology, pseudoaneurysm, ultrasound

INTRODUCTION

Transfemoral vascular access is the most commonly used approach for diagnostic and interventional cardiovascular procedures. Traditionally performed using the Seldinger technique guided by pulse palpation and fluoroscopy, optimal arterial puncture targets the common femoral artery (CFA) or vein below the inguinal ligament and over the femoral head, where complication rates are lowest.¹ Accurate localization based solely on anatomical landmarks, however, may be challenging in patients with obesity, weak pulses, peripheral arterial disease, or altered vascular anatomy. The increasing use of large-bore sheaths, particularly in transcatheter aortic valve implantation (TAVI) and other structural heart interventions, has further reduced the margin for error. As high-risk patient populations increasingly come to the forefront in procedures such as TAVI, this issue becomes even more important.² Proximal punctures increase the risk of retroperitoneal hemorrhage,

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whereas distal or bifurcation-level access is associated with higher rates of bleeding, pseudoaneurysm formation, and vascular injury.^{3,4}

Ultrasound (US)-guided vascular access enables real-time visualization of vascular anatomy and needle trajectory and has been associated with higher first-pass success and fewer vascular complications compared with conventional techniques.⁵⁻⁷ Despite growing evidence, routine adoption remains inconsistent, and real-world data in large-bore structural heart procedures, including combined arterial-venous access, remain limited. The present study aimed to compare US-guided and fluoroscopy-guided transfemoral access in patients undergoing TAVI and left atrial appendage closure, and to evaluate whether US guidance reduces bleeding and vascular complications using propensity score-matched analysis.

METHODS

Study Design and Patient Population

This single-center retrospective observational cohort study included 165 consecutive patients who underwent transfemoral vascular access for structural heart interventions between January 2022 and December 2024.

Patients were stratified according to access type:

- Venous access cohort: left atrial appendage closure (LAAC) (n = 72)
- Arterial access cohort: transcatheter aortic valve implantation (TAVI) (n = 93)

Arterial and venous procedures were analyzed separately owing to differences in vascular anatomy, sheath size, anticoagulation management, and hemostasis strategies. Exclusion criteria included known hematological disorders associated with bleeding diathesis, active malignancy, and complex procedures requiring multiple vascular access sites during a single session.

Patients' baseline demographic, clinical, and laboratory data were extracted from their electronic hospital records. The study adhered to the principles outlined in the Declaration of Helsinki and received approval from the Institutional Ethics Committee (approval date: May 6, 2025; approval number: 25/402). Before the procedures, written informed consent was obtained from all patients.

HIGHLIGHTS

- Femoral access technique represents a modifiable determinant of procedural safety.
- Routine integration of real-time ultrasound (US) guidance during transfemoral arterial access may reduce access-site morbidity in contemporary structural heart practice.
- Given its low cost and broad availability, US guidance represents a pragmatic strategy to improve vascular safety in large-sheath interventions.

Vascular Access Technique

All procedures were performed using a dedicated angiography suite by an experienced interventional cardiologist to ensure procedural consistency. The interventional cardiologist performing the procedures had completed more than 100 US-guided arterial punctures before the study period, ensuring that the technique was applied beyond its established learning curve. All TAVI procedures were performed under deep procedural sedation administered by dedicated anesthesiologists according to a uniform institutional protocol; general anesthesia with endotracheal intubation was not used. All LAAC procedures were performed under general anesthesia with endotracheal intubation. Because anesthesia and fluid management were uniform within each cohort, and arterial and venous procedures were analyzed separately, anesthesia- and fluid-related variability did not affect the comparison between US-guided and conventional access. The right common femoral region was used as the default access site in all patients.

In the ultrasound-guided (USG) group, real-time US guidance (Vivid S6™, GE Healthcare, USA) was used to visualize vascular anatomy, confirm vessel patency, and guide needle entry. Ultrasound-guided puncture was performed using a short-axis (out-of-plane) view of the common femoral artery with a vertical needle approach, targeting the anterior wall of the vessel below the inguinal ligament and above the femoral bifurcation. In the conventional group, femoral access was obtained in every patient using a combination of manual pulse palpation and fluoroscopic guidance of the femoral head; US was not used. No patient in this group underwent palpation-only access, and the combined palpation-plus-fluoroscopy technique was applied uniformly. For venous access, US was used in the same short-axis (out-of-plane) view with a vertical needle approach. The common femoral vein was identified medial to the artery, confirmed by its compressibility and non-pulsatile flow, and the anterior wall was punctured below the inguinal ligament.

Allocation to USG vs. conventional access was not protocol-driven but reflected operator discretion, decided on a per-case basis immediately before each procedure. Conventional cases corresponded to an earlier period of practice, whereas US guidance was progressively adopted over time; US was not preferentially reserved for higher-risk patients. Baseline characteristics, including body mass index and peripheral arterial disease, were comparable between groups (Table 1).

Sheath sizes ranged from 8F to 12F in the venous cohort (LAAC), whereas all arterial procedures (TAVI) were performed using 14F sheaths.

Hemostasis Strategy

Hemostasis techniques differed according to procedure type:

- Venous access (LAAC): manual compression or figure-of-eight suture technique.⁸
- Arterial access (TAVI): suture-mediated closure using a ProGlide™ device (Abbott Vascular, Santa Clara, CA, USA)

Table 1. Baseline Characteristics

Variables	(n=165)
Age (mean $\pm$ SD)	71.6 $\pm$ 10.3
Sex	74 (44.8)
Male, n (%)	91 (55.2)
Female, n (%)	
CAD, n (%)	66 (40.0)
HT, n (%)	121 (73.0)
DM, n (%)	77 (46.5)
CKD, n (%)	13 (7.8)
HFrEF, n (%)	35 (21.2)
AF, n (%)	86 (52.1)
BMI, kg/m ² (mean $\pm$ SD)	25 $\pm$ 2.7
Arterial puncture, n (%)	93 (56.4)
Venous puncture, n (%)	72 (43.6)
Total USG-guided puncture, n (%)	57 (34.5)

AF, atrial fibrillation; BMI, body mass index; CAD, coronary artery disease; CKD, chronic kidney disease; DM, diabetes mellitus; HFrEF, heart failure with reduced ejection fraction; HT, hypertension; USG, ultrasonography.

Regardless of the primary hemostasis method, all patients received adjunctive manual compression followed by pressure bandaging to standardize post-procedural care.

Periprocedural Outcomes

The primary outcomes were as follows:

Absolute hemoglobin decrease (Δ Hb), defined as the difference between preprocedural hemoglobin and hemoglobin measured on post-procedural day 1. To limit the confounding effect of hemodilution on the absolute hemoglobin decrease, hemoglobin was interpreted together with the complete blood count. A post-procedural decline was attributed to hemodilution rather than true blood loss only when a concordant reduction was observed across all hematological series, and such cases were accounted for during data collection.

Access-site-related vascular complications, including:

- Hematoma
- Pseudoaneurysm
- Arteriovenous fistula

Access sites were systematically evaluated immediately after the procedure and on post-procedural day 1. When complications were suspected, confirmatory imaging was performed using US or computed tomography angiography. Management strategies were recorded for all events.

Hemoglobin decrease was analyzed as a supportive continuous safety parameter, whereas clinically adjudicated bleeding and access-site vascular complications were defined according to the Valve Academic Research Consortium-3 (VARC-3) criteria. Major vascular complications comprised access-related injury resulting in death, major ($\geq$ type 2) bleeding, visceral ischemia, or neurological impairment, or any unplanned vascular intervention or surgery meeting these severity thresholds. Minor vascular complications comprised access-site hematoma, pseudoaneurysm,

arteriovenous fistula, dissection, or closure-device failure not fulfilling major criteria. Bleeding was graded as VARC-3 type 1-4; a hemoglobin decline ≥ 3 g/dL in the absence of hemodilution, or transfusion of 2-4 units, defined type ≥ 2 bleeding. Valve Academic Research Consortium-3 definitions were applied to both cohorts to ensure uniform outcome adjudication.

Statistical Analysis

Comparative analyses between US-guided and conventional access techniques were performed separately for arterial and venous procedures. Normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables were compared using the independent samples t-test, whereas non-normally distributed variables were analyzed using the Mann-Whitney U-test. Categorical variables were compared using the chi-square or Fisher's exact test, as appropriate. Odds ratios (OR) with 95% CI were calculated for categorical outcomes. For analyses with small cell counts, the Haldane-Anscombe correction was applied. To reduce potential confounding, 1 : 1 propensity score matching was performed within the arterial access (TAVI) and venous access (LAAC) cohorts using nearest-neighbor matching without replacement. Covariates included age, body mass index, coronary artery disease, heart failure with reduced ejection fraction, atrial fibrillation, peripheral artery disease, oral anticoagulant use, and antiplatelet use. A 2-sided P-value $<.05$ was considered statistically significant. Statistical analyses were performed using Statistical Package for the Social Sciences version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Study Population

A total of 165 patients (mean age 71.6 ± 10.3 years; 44.8% male) underwent transfemoral structural heart interventions, including 93 arterial access procedures (TAVI) and 72 venous access procedures (LAAC) (Table 1). Ultrasound-guided access was used in 57 procedures (34.5%). The study population had a high burden of comorbidities, including hypertension (73%), diabetes mellitus (46.5%), coronary artery disease (40%), and atrial fibrillation (52.1%) (Table 1). Baseline demographic and clinical characteristics were comparable between the USG-guided and conventional access groups.

Hemoglobin Changes

Hemoglobin decrease from baseline to post-procedural day 1 was significantly smaller in the USG group compared with conventional access group (Table 2). In the venous access cohort, mean hemoglobin reduction was 0.80 ± 0.95 g/dL with USG vs. 1.50 ± 1.11 g/dL with conventional access ($P=.009$). Similarly, in arterial access procedures, hemoglobin reduction was lower with USG (0.58 ± 0.97 g/dL vs. 1.29 ± 1.00 g/dL; $P=.002$).

Access-site Complications

Access-site vascular complications differed according to access type. In the venous access cohort, complication rates were low and did not significantly differ between USG-guided

Table 2. Hemoglobin Change After Procedure

Variables	USG-Guided Puncture	Conventional Puncture	P
Venous access			
Number of patients, n	26	46	
Hb drop, g/dL (mean $\pm$ SD)	0.80 $\pm$ 0.95	1.50 $\pm$ 1.11	.009
Arterial access			
Number of patients, n	31	62	
Hb drop, g/dL (mean $\pm$ SD)	0.58 $\pm$ 0.97	1.29 $\pm$ 1.00	.002

Hb, hemoglobin; USG, ultrasonography.

and conventional access (3.8% vs. 17.4%; OR=0.27, $P=.143$) (Table 3). In contrast, arterial access procedures demonstrated significantly fewer complications with US guidance. Overall access-site complications occurred in 3.2% of the USG-guided group compared with 21.0% of the conventional group (OR=0.18, ARR=17.8%, NNT=6) (Table 4). Individual complications, including hematoma, pseudoaneurysm, and arteriovenous fistula, were numerically less frequent in the USG group but did not reach statistical significance because of low event numbers (Table 4).

When reclassified by VARC-3 criteria, no major vascular complications or type ≥ 3 bleeding events occurred in any group. All recorded events were minor vascular complications, which were significantly less frequent with US guidance in the arterial cohort (3.2% vs. 21.0%; OR=0.18, $P=.030$, 95%CI: 0.03-1.03) and numerically lower in the venous cohort (3.8% vs. 17.4%; OR=0.27, $P=.143$, 95%CI: 0.04-1.62). Valve Academic Research Consortium-3 type ≥ 2 bleeding was infrequent and did not differ significantly between groups (arterial 3.2% vs. 6.5%, $P=.660$; venous 0% vs. 8.7%, $P=.290$). No patient required transfusion or surgical repair (Table 5).

Management of Complications

Access-site hematomas were managed with manual compression in both groups, and no patients required blood transfusion or surgical intervention. In the venous cohort, arteriovenous fistulas were treated with percutaneous closure using covered stent grafts. In the arterial cohort, no arteriovenous fistulas occurred in the USG-guided group, whereas cases in the conventional group were managed percutaneously. Pseudoaneurysms were treated with manual compression or US-guided compression therapy.

Propensity Score—Matched Analysis

After 1 : 1 propensity-score matching on age, body mass index, coronary artery disease, heart failure with reduced ejection fraction (HFrEF), atrial fibrillation, peripheral artery

disease, oral anticoagulant use, and antiplatelet use, 31 TAVI and 26 LAAC pairs were generated, with standardized mean differences improving for all covariates after matching. In the matched TAVI cohort, vascular complications were significantly less frequent with US guidance (1/31 [3.2%] vs. 9/31 [29.0%]; $P=.013$), whereas in the matched LAAC cohort, the difference was numerically lower but not significant (1/26 [3.8%] vs. 3/26 [11.5%]; $P=.610$) (Table 6).

DISCUSSION

In this real-world cohort, US-guided femoral access was associated with reduced periprocedural hemoglobin decline and fewer access-site vascular complications, with the greatest benefit observed in large-bore arterial procedures. These findings are consistent with prior randomized trials and meta-analyses demonstrating improved first-pass success and lower bleeding risk with US-guided access compared with landmark-based techniques.^{6,79} The results of this study extend this evidence to contemporary structural heart interventions and demonstrate persistence of benefit after adjustment for baseline comorbidities.

The consistent reduction in hemoglobin decline across both arterial and venous procedures suggests that improved puncture precision represents the principal mechanism underlying the observed benefit. Real-time visualization of the CFA facilitates puncture above the bifurcation and below the inguinal ligament, thereby reducing posterior wall injury and low punctures—mechanisms strongly associated with hematoma and pseudoaneurysm formation.^{3,10,11}

The effect was most pronounced in TAVI procedures, where large-bore sheaths amplify the clinical consequences of suboptimal access. Despite advances in device profiles and vascular closure systems, vascular complications remain an important contributor to early morbidity following transfemoral TAVI.^{3,12} Registry-based and propensity-adjusted studies have demonstrated that US-guided CFA puncture reduces low or bifurcation punctures, key determinants of vascular complications in large-bore access.^{3,9} Notably, these benefits appear largely independent of sheath size or closure strategy, supporting the concept that access technique itself remains a critical and modifiable procedural factor. Management of complications in the present study was consistent with contemporary clinical practice.^{13,14}

The findings of this study align with Lankisch et al¹⁵, whose intra-operator analysis of 1026 transfemoral TAVI procedures showed that switching from fluoroscopy- to US-guided access reduced composite vascular and bleeding complications from 16.1% to 8.3% (adjusted OR=0.46 for VARC-3

Table 3. Puncture-Related Complications After Venous Access

Variables	USG-Guided Puncture	Conventional Puncture	OR (95% CI)	P
Hematoma, n (%)	1 (3.8)	6 (13.0)	0.37 (0.06-2.32)	.410
Arteriovenous fistula, n (%)	0 (0.0)	2 (4.3)	0.34 (0.02-7.27)	.532
Overall complications*, n (%)	1 (3.8)	8 (17.4)	0.27 (0.04-1.62)	.143

OR, odds ratio; USG, ultrasonography.

*Overall complications include hematoma and arteriovenous fistula.

Table 4. Puncture-Related Complications After Arterial Access

Variables	USG-Guided Puncture	Conventional Puncture	OR (95% CI)	P
Hematoma, n (%)	0 (0.0)	6 (9.7)	0.14 (0.01-2.53)	.173
Pseudoaneurysm, n (%)	1 (3.2)	6 (9.7)	0.43 (0.07-2.66)	.418
Arteriovenous fistula, n (%)	0 (0.0)	2 (3.2)	0.38 (0.02-8.25)	.551
Overall complications*, n (%)	1 (3.2)	13 (21.0)	0.18 (0.03-1.03)	.03

OR, odds ratio; USG, ultrasonography.

*Overall complications include hematoma, pseudoaneurysm, and arteriovenous fistula.

Table 5. VARC-3 Classification

Outcome	USG-Guided Arterial Puncture (n = 31)	Conventional Arterial Puncture (n = 62)	P	USG-Guided Venous Puncture (n = 26)	Conventional Venous Puncture (n = 46)	P
Major vascular complication	0	0	—	0	0	—
Minor vascular complication	1 (3.2)	13 (21.0)	.030	1 (3.8)	8 (17.4)	.143
VARC-3 type ≥ 2 bleeding	1 (3.2)	4 (6.5)	.660	0 (0.0)	4 (8.7)	.290
VARC-3 type $\geq 3/4$ bleeding	0	0	—	0	0	—

USG, ultrasonography; VARC-3, Valve Academic Research Consortium-3.

bleeding), an effect seen even among operators already experienced with angiographic access.

In contrast, venous access has received comparatively limited attention in studies evaluating US guidance. In the present cohort, US-guided venous access was associated with numerically fewer complications and significantly smaller hemoglobin decline, although categorical differences did not reach statistical significance, likely owing to limited event numbers. Existing literature in structural and electrophysiological procedures has largely focused on hemostasis strategies rather than puncture technique.^{16,17} These findings therefore provide incremental real-world evidence supporting a potential safety benefit of US guidance during venous large-sheath procedures such as LAAC.

After propensity score matching, residual imbalance persisted for oral anticoagulant use in both cohorts and for atrial fibrillation in the LAAC cohort, reflecting the near-universal prevalence of atrial fibrillation and anticoagulation among patients undergoing LAAC. Because anticoagulation was more frequent in the conventional arm, this residual imbalance biases against US guidance and renders the observed benefit conservative rather than overstated.

The biological and procedural plausibility of these observations is well supported. A further mechanistic advantage of US is the direct visualization of arterial wall calcification. Anterior-wall or circumferential calcific plaque at the intended puncture site is poorly appreciated on fluoroscopy but readily identified on US, allowing the operator to select a calcium-free segment for needle entry. This is particularly relevant when suture-mediated closure devices such as ProGlide (Abbott Vascular, USA) are used, since puncture through a calcified arterial segment is a recognized cause of closure-device failure and consequent access-site bleeding; avoiding calcified segments may therefore reduce both puncture-related injury and closure-device failure in large-bore arterial procedures. Imaging and procedural studies consistently demonstrate that malpositioned femoral

punctures remain a major determinant of access-site morbidity, even in experienced centers.¹⁸ Ultrasound guidance therefore represents a simple and reproducible strategy to mitigate anatomically driven complications that are not addressed by closure devices alone.

Several limitations should be acknowledged. First, the retrospective single-center design limits causal inference and may allow residual confounding despite propensity score matching. Second, the relatively small sample size and low event rates—particularly in the venous cohort—may have reduced statistical power for categorical outcomes. Third, detailed femoral anatomical characteristics were not systematically quantified. Finally, first-pass puncture success was not systematically recorded and could not be analyzed; as improved first-pass success is a recognized mechanism of benefit of US guidance, its absence limits mechanistic inference. In addition, access sites were assessed immediately after the procedure and on post-procedural day 1 only; delayed complications such as late pseudoaneurysm or arteriovenous fistula arising after discharge may have been underascertained, since systematic 30-day vascular follow-up was not available. Nevertheless, the consistency of findings across unadjusted and matched analyses, together with the magnitude of effect observed in the arterial cohort, supports the internal validity of the study and highlights femoral access technique as a clinically relevant and modifiable determinant of transfemoral procedural safety.

Table 6. Results of Propensity Score–Matched Analysis for Vascular Complications

Cohort	Matched Pairs	USG-Guided	Conventional	P
Arterial	31	1 (3.2)	9 (29.0)	.013
Venous	26	1 (3.8)	3 (11.5)	.610

Data are presented as number (percentage).

USG, ultrasonography.

P value calculated using Fisher's exact test.

CONCLUSION

In this real-world cohort of structural heart interventions, US-guided transfemoral access was associated with reduced periprocedural hemoglobin decline and fewer access-site vascular complications, with the greatest benefit observed in large-bore arterial procedures. These findings support US guidance as a simple and reproducible strategy to improve vascular access safety in contemporary transfemoral interventions. Prospective multicenter studies are warranted to confirm these observations and to define the role of routine US guidance across both arterial and venous structural procedures.

Ethics Committee Approval: This study was approved by the Ethics Committee of Hacettepe University (Approval No: 25/402, Date: May 6, 2025).

Informed Consent: The requirement for informed consent was waived by ethics committee due to retrospective design of the study. Peer-review: Externally peer-reviewed.

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SUPPLEMENTARY MATERIAL

Supplementary Material for Table 6

Covariate	Arterial before	Arterial after	Venous before	Venous after
Age	−0.19	−0.05	0.15	0.03
BMI	−0.24	0.08	0.18	0.04
CAD	−0.30	−0.20	−0.04	0.09
HFrEF	−0.43	0	0.03	0
AF	−0.58	−0.14	1.17	0.34
PAD	0	−0.15	−0.03	0
OAC	−0.46	−0.33	0.51	0.46
Antiplatelet	−0.07	0.07	0.31	0.27