



Outcomes of ultrasound-guided and conventional Angio-Seal closure following antegrade femoral artery access: a systematic review and meta-analysis of observational studies with an exploratory indirect comparison

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PURPOSE

Vascular closure devices (VCDs), particularly the Angio-Seal device, are widely used for rapid hemostasis following antegrade femoral artery access during peripheral vascular interventions. However, the comparative safety and efficacy of ultrasound-guided vs. conventional non-ultrasound-guided antegrade femoral access closure with Angio-Seal have not been quantified. This meta-analysis synthesizes available evidence comparing these approaches in patients undergoing antegrade femoral artery access closure with Angio-Seal devices.

METHODS

Relevant studies were systematically identified through searches of the PubMed and Google Scholar databases. Studies examining the Angio-Seal closure device for antegrade femoral artery access closure with ultrasound-guided and conventional (without ultrasound guidance) techniques and comparing the two techniques were included. Given the limited direct comparative evidence, pooled outcomes from ultrasound-guided and non-ultrasound-guided cohorts were evaluated. The primary endpoints were technical success rates, major complications, and minor complications. Study quality was assessed using the Newcastle–Ottawa Scale, and data were extracted systematically. A meta-analysis was conducted using random-effects models, with odds ratios (ORs) and 95% confidence intervals (CIs) as effect measures. In addition, Grading of Recommendations Assessment, Development, and Evaluation (GRADE) analysis of the certainty of the obtained evidence was performed.

RESULTS

The search identified 15 studies comprising 4,782 antegrade femoral access closures using the Angio-Seal device. The pooled technical success rate was 96.3% (95% CI: 0.93–0.98), with considerable heterogeneity (I^2 : 86%). Major complications were rare, with a pooled rate of 1.1% (95% CI: 0.01–0.02), whereas minor complications occurred in 3.4% (95% CI: 0.03–0.09) of procedures. Substantial and considerable heterogeneity was observed for major and minor complications (I^2 : 66% and 90%, respectively). Comparative analysis demonstrated higher technical success with ultrasound-guided closure than with conventional techniques, corresponding to significantly lower odds of technical failure with ultrasound guidance (OR: 0.13, 95% CI: 0.019–0.962; P = 0.014; GRADE certainty: very low) and significant reduction in the rate of major complications (OR: 0.2, 95% CI: 0.072–0.558; P = 0.00027; GRADE analysis: low); minor complication rates were similar between techniques (OR: 0.82, 95% CI: 0.567–1.19; P = 0.3).

CONCLUSION

Angio-Seal closure following antegrade femoral access demonstrates high technical success and low complication rates across available studies. Ultrasound-guided deployment was associated with higher technical success and reduced major complications in the pooled analysis. However, the evidence is derived primarily from observational studies with considerable heterogeneity, and further prospective studies are needed to confirm these findings.

CLINICAL SIGNIFICANCE

These findings support integrating ultrasound guidance into routine antegrade femoral artery closures to improve procedural safety and enhance operator confidence. Adoption of ultrasound-guided closure techniques may contribute to improved patient outcomes and better post-procedural recovery rates in vascular populations.

KEYWORDS

Ultrasound guidance, Angio-Seal, vascular closure device, antegrade femoral access, meta-analysis

Antegrade femoral artery access is frequently used in the endovascular treatment of infrainguinal peripheral arterial disease. This approach provides direct access to lower limb vessels and improves the pushability and trackability of devices. However, antegrade access presents several technical challenges.¹ A steep puncture angle is required for antegrade access, especially in patients with unfavorable body habitus, which can sometimes result in a kink in the sheath, causing subsequent difficulty in transferring devices both during the procedure and during closure. Additionally, the smaller target zone and proximity to the femoral bifurcation increase the risk of inadvertent superficial femoral artery (SFA) or profunda femoris artery puncture, particularly in patients with obesity, scarring from prior procedures, or anatomical variations.¹⁻³ Collectively, these factors may contribute to the historically reported higher complication rates with antegrade compared with retrograde access. Following these procedures, achieving rapid and reliable hemostasis is critical to minimize access-site complications and facilitate early patient mobilization.

Vascular closure devices (VCDs) have been used widely for achieving rapid hemostasis after arterial access procedures. Among the available VCDs, the Angio-Seal device—a bioabsorbable anchor-and-collagen plug system—has gained widespread adoption due to its ease of use and reliable, rapid deployment.⁴ Angio-Seal offers several theoretical advantages for antegrade access. Unlike suture-mediated devices that require specific sheath sizes and may be technically challenging in steep puncture angles, Angio-Seal can be deployed relatively easily regardless of access angle. The device is available in two sizes (6F and 8F) to accommodate the different sheath sizes commonly used in peripheral interventions. Technical success rates for Angio-Seal in antegrade access have been reported as 92%–98% among experienced surgeons. However, Angio-Seal deployment in antegrade access is not without risks. Major complications include arterial occlusion (particularly in small-caliber vessels such as the SFA), device embolization, pseudoaneurysm, arterial dissection, and infection. Minor complications include hematoma, access-site pain, and ecchymosis. Complication rates vary widely in the literature, ranging from 0% to 19.2%.^{3,5-9}

Ultrasound guidance has become nearly universal for central venous access and is increasingly adopted for arterial access proce-

dures. For femoral artery access, ultrasound guidance enables precise identification of the common femoral artery (CFA) and avoidance of inadvertent puncture of the SFA, profunda femoris artery, or femoral vein. This is particularly valuable in antegrade access, where the target zone is smaller and the consequences of suboptimal puncture are more severe. Multiple randomized controlled trials and meta-analyses have demonstrated that ultrasound-guided femoral access reduces access-site complications, improves first-pass success rates, and decreases time to successful access compared with anatomical landmark-based techniques.^{2,10-13}

The application of ultrasound guidance specifically for VCD deployment represents a logical extension of its use for initial access. Ultrasound can be employed at multiple stages of VCD closure: pre-deployment assessment of the puncture site and surrounding anatomy, real-time visualization during device deployment to confirm appropriate positioning, and post-deployment assessment to detect immediate complications such as arterial dissection, thrombosis, or device malposition.^{6,10,14,15} For Angio-Seal specifically, ultrasound can confirm that the intravascular anchor is properly positioned within the arterial lumen and that the collagen plug achieves adequate hemostasis without causing arterial stenosis or occlusion.^{6,10,16}

Despite these theoretical advantages, the incremental benefit of ultrasound guidance for VCD closure beyond its use for initial access remains debated. Most operators are of the opinion that once optimal access is achieved with ultrasound guidance, subsequent VCD deployment can proceed without imaging guidance. Occasional operators contend that ultrasound guidance throughout access and closure provides additional safety benefits by enabling real-time monitoring and immediate detection of complications.^{6,16} The evidence base supporting these competing perspectives is limited, necessitating a systematic synthesis of available data.

This systematic review and meta-analysis aims to evaluate the safety and efficacy of Angio-Seal closure following antegrade femoral artery access and to explore differences in outcomes between ultrasound-guided and conventional non-ultrasound-guided closure. Specifically, this study sought to compare technical success rates and rates of major and minor complications.

Methods

Literature search strategy and study selection

A literature search was performed to identify all relevant studies examining the use of the Angio-Seal VCD for antegrade femoral artery access, with particular focus on comparisons between ultrasound-guided and conventional non-ultrasound-guided closure techniques. The search was performed across multiple electronic databases and platforms through February 2026. The search string utilized was as follows: (antegrade OR anterograde OR ante-grade) AND (femoral) AND (vascular closure device OR VCD OR Angioseal OR Angio-Seal). The reference lists of included studies and relevant systematic reviews were manually searched to identify further eligible studies.

Inclusion and exclusion criteria

All studies comparing ultrasound-guided vs. conventional closure techniques or single-arm studies reporting outcomes with either technique using Angio-Seal for antegrade femoral access for treatment of peripheral vascular disease in adult patients were considered for analysis. The studies had to report on at least one of the following outcomes: technical success rate, major complications (arterial occlusion or stenosis needing treatment, pseudoaneurysm, major bleeding requiring transfusion or surgical intervention, arterial dissection, and arteriovenous fistula), and minor complications (hematoma not requiring care escalation, minor bleeding, access-site pain, and ecchymosis). There were no restrictions on the duration of follow-up. Duplicate publications, case reports, and conference abstracts were excluded. Studies focusing exclusively on retrograde femoral access, studies examining closure devices other than Angio-Seal, studies without details on Angio-Seal-specific or antegrade-specific outcomes, studies in the pediatric population, studies without extractable outcome data, case reports, case series with fewer than five patients, and studies on non-femoral arterial access sites were excluded.

Data extraction methods

Data extraction was performed by two investigators systematically using a standardized data extraction form. For each included study, the data elements were categorized as follows: year of study; study characteristics including design and sample size; pa-

tient characteristics including age, sex, body mass index, comorbidities, and antiplatelet/anticoagulation therapy; procedural characteristics including the access site (CFA, SFA, or both), sheath size, and use of ultrasound guidance for access and closure; outcome data including the technical success rate, major complications (arterial stenosis or occlusion requiring intervention, pseudoaneurysm, major bleeding requiring transfusion or surgical repair, arterial dissection, and device embolization), and minor complications (hematoma, minor bleeding not requiring intervention, arterial stenosis not needing intervention, access-site pain, and ecchymosis); and the duration of follow-up. Data were extracted independently by two of the authors, and discrepancies, when seen, were resolved through discussion or consultation with a third author.

Quality assessment

The Newcastle–Ottawa Scale (NOS) was used for cohort and case–control studies, assessing three domains: the selection of study groups (maximum of 4 stars), the comparability of groups (maximum of 2 stars), and ascertainment of outcomes (maximum of 3 stars). Studies scoring 7–9 stars were considered high quality, 4–6 stars moderate quality, and 0–3 stars low quality. Quality assessment was performed independently by two reviewers, and disagreements were resolved by consensus.

Statistical methods

In view of the expected heterogeneity resulting from differences in study populations, follow-up duration, and assessment methods, a random-effects model was applied throughout the analysis. The analysis compared two interventions: ultrasound-guided Angio-Seal closure and conventional

(non-ultrasound-guided) Angio-Seal closure of antegrade femoral access. For binary outcomes, odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were calculated according to Altman (1991). P values were calculated separately using the two-sided Fisher’s exact test, with $P < 0.05$ considered statistically significant, using MedCalc Software Ltd, Version 23.4.9 (Ostend, Belgium). Study-level event rates and 95% CIs were calculated using the inverse-variance method, and the Freeman–Tukey double arcsine transformation was used to construct relevant forest plots using metaanalysisonline.com.

Between-study heterogeneity was assessed using Cochran’s Q test (reported as the χ^2 statistic with corresponding P values) and the I^2 statistic, which quantifies the percentage of total variation attributable to between-study differences rather than chance. The I^2 values were interpreted as low (0%–40%), moderate (30%–60%), substantial (50%–90%), and considerable ($> 75\%$) heterogeneity, respectively. The between-study variance (τ^2) was estimated using the DerSimonian–Laird method, and 95% prediction intervals were calculated to estimate the range within which the true effect of a future study is expected to lie, accounting for between-study heterogeneity. Analysis of publication bias was not performed due to the small number of studies included (< 15).

Results

Study selection

The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) 2020 reporting guidelines. A search for articles was performed in PubMed and Google Scholar to identify relevant studies evaluating the safety and efficacy of the Angio-Seal VCD following antegrade femoral arterial access.

The initial database search yielded 702 records. Following the removal of duplicates (72) and title screening to exclude unrelated topics (587), a full-text review was performed to determine the eligibility of 43 studies. Twenty-eight studies were excluded for predefined reasons: a non-study article/commentary (1); the lack of details of antegrade access or Angio-Seal cohorts (20); the use of imaging other than ultrasound for closure (1); and studies not involving antegrade femoral access (6). After the application of the predefined inclusion and exclusion criteria,

15 studies were obtained for meta-analysis.^{3,5-8,10,17-25} The study selection process is illustrated in the PRISMA 2020 flow diagram (Figure 1).

Study characteristics

The included studies originated from diverse geographic regions, including Europe, North America, and Asia, with representation from the United Kingdom, Italy, Germany, Ireland, the Netherlands, Türkiye, Singapore, the United States, Canada, and multicenter European registries (Table 1). Most included studies were retrospective cohort studies, with one prospective cohort study (Minko et al.⁵), one prospective registry study (Reekers et al.²³), one retrospective matched cohort study (Çabuk and Çabuk²⁵), and one case series (Biondi-Zoccai et al.⁷). One study¹⁰ reported exclusively on ultrasound-guided closure with Angio-Seal, and another study⁶ reported a comparison of both ultrasound-guided and non-ultrasound-guided closure. The remaining studies reported exclusively on closure without imaging guidance.

Sample sizes differed considerably across studies, ranging from 5 to 1,889 puncture site closures, reflecting considerable heterogeneity in study populations. Larger cohort studies included those by Lupattelli et al.,²⁴ which analyzed 1,889 antegrade punctures, and Ong et al.,⁶ which included 1,322 patients undergoing Angio-Seal closure, whereas smaller studies such as that by Biondi-Zoccai et al.⁷ included only 5 patients. Participant mean ages ranged from 56 to 75 years across studies. In some studies, antegrade access-site closure with Angio-Seal was compared with manual compression, retrograde access closure, or between different puncture locations, such as CFA vs. SFA.

Follow-up duration showed substantial variability among studies. Some studies evaluated outcomes only during the in-hospital or immediate post-procedural period, whereas others included longer follow-up periods ranging from 6–8 weeks to 3 months, and up to 18 months in the study by Lupattelli et al.²⁴

Patient and procedure characteristics

Across the 15 included studies, the demographic characteristics reported were largely comparable, with a high prevalence of diabetes mellitus (72%–100%, pooled average 92.2%), hypertension (48%–90%, pooled average 71.5%), and coronary artery disease (53%–57%, pooled average 53.8%). Chronic kidney disease was reported in two studies

Main points

- Angio-Seal closure for antegrade access is generally effective with low complication rates.
- Ultrasound guidance is associated with improved success and safety for antegrade femoral artery closure with Angio-Seal, with 87% lower odds of technical failure and 80% lower odds of major complications compared with conventional (non-ultrasound-guided) techniques.
- Although ultrasound guidance demonstrates benefits for critical outcomes, its impact on minor complications is less conclusive, suggesting that its primary advantage lies in preventing more severe issues.

(13%)^{10,25}. A high pooled average for diabetes mellitus was strongly influenced by the large-sample cohort study by Lupattelli et al.,²⁴ which exclusively enrolled patients with diabetes combined with critical ischemia. Across the included studies, critical limb ischemia (CLI) represented a common indication for intervention, reported in 91.4% of cases in the study by Akard et al.,³ 87.2% in

the study by Ipema et al.,¹⁰ and in all patients in the study by Biondi-Zoccai et al.,⁷ whereas Çabuk and Çabuk²⁵ reported CLI as the indication for intervention in approximately half of their cohort.

Ultrasound was used for access in all studies reporting ultrasound-guided closure and in four studies reporting non-ultra-

sound-guided closure (Akard et al.,³ Adlan et al.,¹⁷ Çabuk and Çabuk²⁵, Cicuto et al.¹⁸). In one study, ultrasound was used in 14/50 cases after failed fluoroscopic landmark-guided puncture (Looby et al.²⁰). Some studies contained criteria for patient inclusion for Angio-Seal closure. Patients in the study by Adlan et al.¹⁷ underwent Angio-Seal for closure if the puncture site artery was at least

Table 1. Characteristics of included studies

Author (year)	Country	Study design	Sample size	Mean age (years)	Intervention / comparator	Follow-up duration	Key outcomes
Ong et al., ⁶ 2023	Singapore	Retrospective cohort	1,322 patients (1,131 US-guided closures and 191 non-US-guided closures)	NR	US-guided vs. non-US-guided Angio-Seal closure	In-hospital complications	Adverse events, severe complications
Adlan et al., ¹⁷ 2017	United Kingdom	Retrospective cohort	194 patients (228 closures, CFA in 70, and SFA in 158)	74	Angio-Seal closure in SFA vs. CFA punctures	16 months	Hemostasis success, complications
Akard et al., ³ 2018	United States	Retrospective cohort	88 patients (140 punctures)	69.2	Angio-Seal closure following SFA access	In hospital and clinical follow-up at 1 and 6 months	Access-related complications
Chaudhuri et al., ⁸ 2014	United Kingdom	Retrospective analysis	271 closures	73.1	Angio-Seal in antegrade vs. retrograde punctures	NR	Deployment success and failure rates
Cicuto et al., ¹⁸ (poster)	United States	Observational study	50	NR	Angio-Seal following antegrade SFA access	In hospital	Safety and efficacy
Ipema et al., ¹⁰ 2023	Netherlands	Retrospective cohort	187 closures (173 CFA and 14 SFA closures)	75	US-assisted Angio-Seal closure	6–8 weeks	Technical success, major and minor complications
Kapoor et al., ¹⁹ 2007	Canada/USA	Retrospective cohort	55 patients (56 CFA closures)	37–94 (range)	Angio-Seal closure after antegrade CFA puncture	NR	Technical success, complications
Looby et al., ²⁰ 2008	Ireland	Retrospective cohort	50 closures	68.8	Angio-Seal vs. manual compression	24 hours (discharge outcomes)	Hemostasis success, complications
Lupattelli et al., ²⁴ 2010	Italy	Retrospective cohort	1,889 closures	69	Angio-Seal vs. manual compression/retrograde closure	3 months on average, up to 18 months	Technical success, complication rates
Minko et al., ⁵ 2012	Germany	Prospective cohort	120 closures	70	Angio-Seal closure device	Short-term procedural outcomes	Hemostasis success, risk factors
Modi et al., ²¹ 2013	United Kingdom	Retrospective observational	122 closures	NR	Angio-Seal closure device	Short-term follow-up	Device success, complications
Mukhopadhyay et al., ²² 2005	United Kingdom	Retrospective cohort	21 patients	70.5	Angio-Seal closure device	Post-procedure follow-up	Complications and success
Reekers et al., ²³ 2011 (CIRSE registry)	Multicenter Europe (10 countries)	Prospective registry study	169	55–75-year age distribution	Closure devices with anchor-plug mechanism (Angio-Seal)	In hospital	Deployment success, bleeding, device-related complications
Biondi-Zoccai et al., ⁷ 2007	Italy	Case series	5 patients	NR	Angio-Seal closure after antegrade femoral access for below-knee angioplasty	In hospital	Immediate hemostasis in all patients with no major complications
Çabuk and Çabuk, ²⁵ 2025	Türkiye	Retrospective matched cohort study	52	56.2	Angio-Seal VIP vs. manual compression	3 months	Hemostasis success 92.3% vs. 90.4%, comparable complication rates, shorter hospitalization with Angio-Seal

US, ultrasound; CFA, common femoral artery; SFA, superficial femoral artery; NR, not reported.

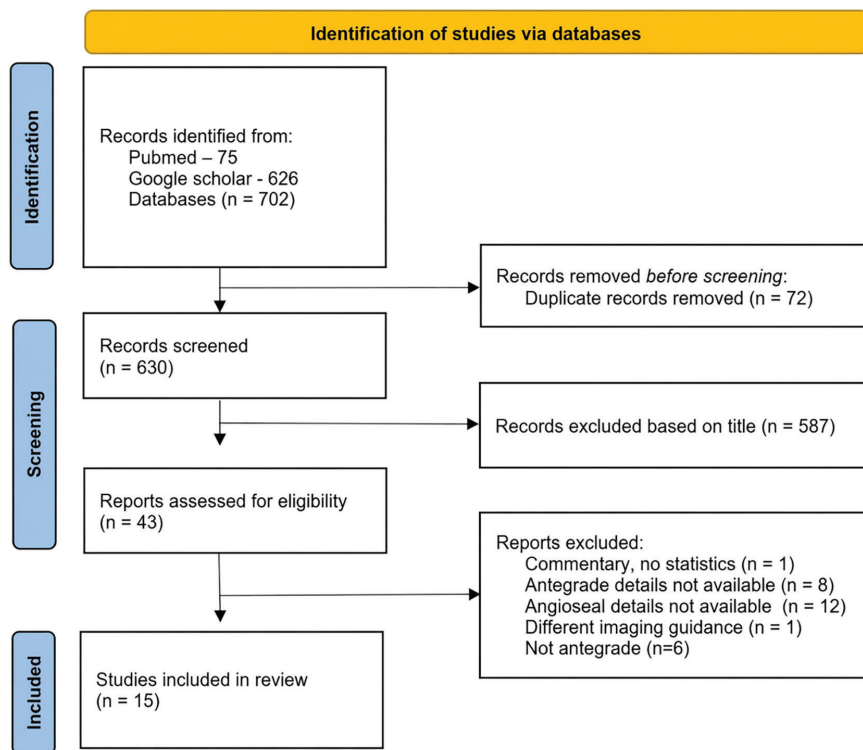


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses flowchart for the selection of studies reporting on outcomes of technical success and complications of Angio-Seal deployment after percutaneous antegrade femoral artery access.

6 mm in diameter and had no anterior wall plaque, whereas the patients in the study by Akard et al.³ were evaluated with ultrasound for the same reason, but no minimum vessel diameter criteria are mentioned in the study. A computed tomography angiogram was reviewed for CFA disease in the study by Kapoor et al.¹⁹ Angio-Seal was not used for closure if the puncture site showed moderate-to-severe plaque; no puncture site diameter measurements were included. The largest non-ultrasound-guided Angio-Seal deployment study, by Lupattelli et al.,²⁴ evaluated all patients with Doppler at the iliofemoral and popliteal segments and excluded patients from Angio-Seal closure who had a puncture at the bifurcation or if angioplasty of the SFA ostium was performed; femoral access was not performed if there was fibrosis, prior local vascular surgery, obesity, or absent bilateral femoral pulses, and antegrade access was not chosen if Doppler showed 50% stenosis at the CFA or occlusion of the SFA at origin. In the study by Çabuk and Çabuk,²⁵ patients with > 50% proximal SFA disease, moderate-to-heavy puncture site calcification, or the presence of a bypass graft at the puncture site were excluded from Angio-Seal usage for closure. In the study by Looby et al.,²⁰ Angio-Seal was not used if severe plaque or multiple plaques were identified in the CFA.

The included studies described the use of 6F sheaths for most patients, with larger sizes used only in a minority of cases. The largest sheath size reported in the studies was 9F; for example, in the study by Chaudhuri et al.,⁸ 4 patients had a 9F sheath placed for endovascular treatment of a popliteal artery aneurysm. Intraprocedural heparin administration was routine across most studies, with doses ranging from 3,000 to 5,000 IU; in some cases, it was titrated to maintain an activated clotting time of > 250 seconds. Heparin reversal before closure was reported in 3 patients out of 140 in the study by Akard et al.³ Looby et al.²⁰ reported that most patients received aspirin therapy during the intervention, and Biondi-Zoccai et al.⁷ described more intensive antithrombotic regimens, including heparin, aspirin, and clopidogrel, in all patients, with additional glycoprotein IIb/IIIa inhibitor therapy in two cases and fibrinolytic therapy in one case.

Post-Angio-Seal deployment management varied across the included studies but generally involved short periods of bed rest, with or without adjunctive compression. Several studies reported relatively brief immobilization times following Angio-Seal deployment. Akard et al.³ and Chaudhuri et al.⁸ reported 2 hours of bed rest following closure, Kapoor et al.¹⁹ reported 1–2 hours of bed rest and, more recently, Çabuk and

Çabuk²⁵ reported a shorter immobilization protocol, with 1 hour of bed rest. In the study by Ipema et al.,¹⁰ post-procedural immobilization depended on sheath size, with 2 hours of bed rest for 6F and 7F access sites and 4 hours for 8F.

By contrast, some studies implemented longer periods of post-procedural monitoring or compression. Minko et al.⁵ reported 6 hours of bed rest combined with a compression bandage maintained for 24 hours, whereas Biondi-Zoccai et al.⁷ described 12 hours of bed rest with a loose compressive bandage. Lupattelli et al.²⁴ reported that manual compression was applied for approximately 45–60 seconds immediately after Angio-Seal deployment in all patients, followed by 2 hours of bed rest and a compression bandage maintained for 16–24 hours.

Outcomes

Outcome measures were broadly consistent across studies and focused on the technical success of device deployment with successful hemostasis and major or minor vascular complications at the access site. The definition of major and minor complications differed between studies. For this systematic review, arterial stenosis or occlusion requiring intervention, pseudoaneurysm requiring intervention, major bleeding requiring transfusion or surgical repair, arterial dissection, device embolization, and arteriovenous fistula requiring treatment were considered major complications; hematoma and minor bleeding not requiring intervention, arterial stenosis not needing intervention, access-site pain, and ecchymosis were considered minor complications.

Across the included studies, a total of 4,782 antegrade femoral access closures using the Angio-Seal VCD were analyzed. Overall, the device showed high rates of technical success, with most studies reporting successful deployment and immediate hemostasis in most procedures. Reported technical success rates generally ranged from approximately 92% to 100% across individual studies, with studies reporting success rates above 95%, reflecting the reliability of Angio-Seal for achieving rapid hemostasis. A notable outlier was the study by Minko et al.,⁵ which reported a lower technical success rate of 81%. This reduced success rate is likely explained by the absence of exclusion criteria for Angio-Seal use in that study, as patients were included regardless of factors known to complicate vascular closure, including significant vessel calcification, previous surgical intervention, groin fibrosis, occlusion of the

ipsilateral SFA, and obesity. In total, 9 of the 120 patients in this study developed a kink in the Angio-Seal sheath preventing the passage of the Angio-Seal footplate toward the vessel.

Major access-site complications were infrequent across the included studies, with reported rates generally ranging from 0%^{5,7,17,19,22} to 5.8%.²⁵ In several studies, no major complications were reported, whereas others described isolated cases of pseudoaneurysm, significant hematoma, vascular stenosis/occlusion requiring treatment, or arteriovenous fistula needing treatment.

Minor complications occurred somewhat more often, ranging from 0%⁷ to approximately 19.2%⁵ across studies. When all complications were considered together, the overall complication rates reported across studies typically ranged from approximately 1% to 19.2%. Despite variations in study design and patient populations, the overall findings consistently demonstrated high technical success and low complication rates associated with Angio-Seal closure following antegrade femoral access. Table 2 summarizes

the pooled technical success and complication rates across the included studies, with corresponding comparative effect estimates between ultrasound-guided and non-ultrasound-guided closures and certainty of evidence assessment using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework.

Assessment of bias

The NOS was used to assess risk of bias (Table 3). The quality of the evidence ranged largely from moderate to high, with most studies scoring between 6 and 8 stars. Several larger cohort studies, including those by Ong et al.,⁶ Lupattelli et al.,²⁴ Ipema et al.,¹⁰ and the Cardiovascular and Interventional Radiological Society of Europe registry reported by Reekers et al.,²³ demonstrated higher methodological quality resulting from well-defined study populations and clear outcome assessment. Most studies were retrospective observational studies, which limited comparability between cohorts caused by minimal adjustment for potential confounders. Smaller studies and case series, such as that of Biondi-Zoccai et al.,⁷ showed a higher risk

of bias due to limited sample sizes and the absence of control groups. Overall, although the included studies generally demonstrated acceptable methodological quality, the predominance of retrospective designs represents an inherent limitation of this systematic review.

Meta-analysis outcomes

Across the 15 studies included in the pooled analysis, a total of 4,782 antegrade femoral access closures using Angio-Seal were evaluated, comprising 3,364 conventional non-ultrasound-guided closures and 1,318 ultrasound-guided closures. For technical success analysis, Ipema et al.¹⁰ contributed data from 187 ultrasound-guided closures, whereas Ong et al.⁶ provided no extractable technical success data. However, both studies contributed data to the analyses of major and minor complications. High technical success rates were observed in both groups but were higher with ultrasound-guided closures (99.5%) than with non-ultrasound-guided closures (96.1%); ultrasound guidance was associated with significantly lower odds of technical failure

Table 2. Summary of findings for Angio-Seal closure following antegrade femoral access. Pooled technical success and complication rates across the included studies are shown with corresponding comparative effect estimates between ultrasound-guided and conventional closures. Certainty of evidence was assessed using the GRADE framework

Outcome	No. of studies	Total closures	Pooled event rate (95% CI)	Comparative effect (US vs. non-US)			Heterogeneity	Model	Certainty of evidence (GRADE)	Comments
				OR	95% CI	P value				
Technical success	15	3,238	96.3% (0.93–0.98)	0.13*	0.019–0.962*	0.014*	86%	Random effects	Very low ⊕○○○	US-guided closure may increase success, but the evidence is uncertain, based predominantly on retrospective cohort studies with considerable heterogeneity
Major complications	15	4,391	1.1% (0.01–0.02)	0.2	0.072–0.558	0.00027	66%	Random effects	Low ⊕⊕○○	US-guided closure reduces the risk of major complications; the evidence is based predominantly on retrospective cohort studies with substantial heterogeneity
Minor complications	15	4,391	3.4% (0.03–0.09)	0.82	0.567–1.19	0.3	90%	Random effects	Very low ⊕○○○	US guidance does not significantly reduce the risk of minor complications; evidence is based predominantly on retrospective cohort studies with considerable heterogeneity and imprecision [high p-value, and CI crosses line of no effect (1.0)]

*These values represent technical failure; therefore, an OR <1 favors US guidance. US, ultrasound; OR, odds ratio; CI, confidence interval; GRADE, Grading of Recommendations Assessment, Development, and Evaluation.

Study	Selection (0–4)	Comparability (0–2)	Outcome/exposure (0–3)	Total score (0–9)	Quality rating
Adlan et al., ¹⁷	3	1	2	6	Moderate
Akard et al., ³	3	1	2	6	Moderate
Biondi-Zoccai et al., ⁷	2	—	1	3	Low
Çabuk and Çabuk, ²⁵	3	2	2	8	High
Chaudhuri et al., ⁸	3	1	2	6	Moderate
Cicuto et al. ¹⁸	2	1	1	4	Low
Ipema et al., ¹⁰	4	1	3	8	High
Kapoor et al., ¹⁹	3	1	2	6	Moderate
Looby et al., ²⁰	3	1	2	6	Moderate
Lupattelli et al., ²⁴	4	2	3	9	High
Minko et al., ⁵	4	1	3	8	High
Modi et al., ²¹	3	1	2	6	Moderate
Mukhopadhyay et al., ²²	2	1	2	5	Moderate
Ong et al., ⁶	4	1	3	8	High
Reekers et al., ²³	4	1	3	8	High

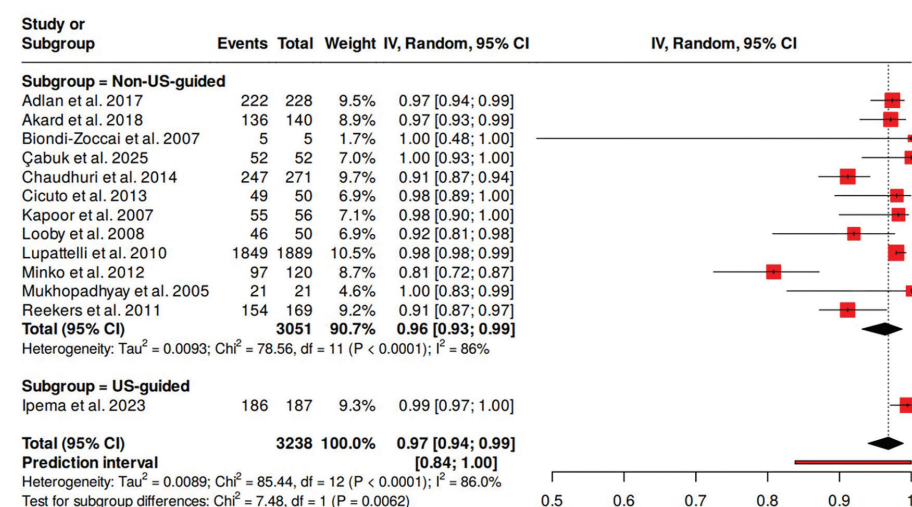


Figure 2. Forest plot of 13 studies, including 3,238 events (access closures), for technical success rates. CI, confidence interval; US, ultrasound.

(OR: 0.13, 95% CI: 0.019–0.962; $P = 0.014$), corresponding to an absolute failure risk reduction of 3.33% and a number needed to treat (NNT) of 30. Between-study heterogeneity was considerable [Cochran's Q (Chi^2): 85.44, df: 12, $P < 0.0001$; I^2 : 86%; τ^2 : 0.0089] (Figure 2).

For major complications, pooled data were available for 1,318 ultrasound-guided and 3,073 non-ultrasound-guided closures. Major complications occurred in 4/1,318 (0.3%) ultrasound-guided cases compared with 46/3,073 (1.5%) non-ultrasound-guided cases. This difference reached statistical significance, with ultrasound guidance reducing the odds of major complications by approximately 80% (OR: 0.20, 95% CI: 0.072–0.558; $P = 0.00027$). Moderate-to-substantial

between-study heterogeneity was observed (Chi^2 : 38.54, df: 13, $P = 0.0002$; I^2 : 66.3%; τ^2 : 0.0020) (Figure 3). This equates to an absolute risk reduction of 1.19%, a relative risk reduction of 79.7%, and an NNT of approximately 84. These findings suggest that ultrasound guidance provides a clinically meaningful reduction in serious access-site complications, even though the absolute event rate was low in both groups.

Although minor complications were somewhat more frequent, their overall incidence remained low. Pooled analysis demonstrated 39 minor complications among 1,318 ultrasound-guided closures (2.9%) and 110 minor complications among 3,073 non-ultrasound-guided closures (3.6%). No statistically significant difference was observed be-

tween groups (OR: 0.82, 95% CI: 0.567–1.19; $P = 0.3$), indicating that ultrasound guidance did not significantly affect the rate of minor access-site complications. Considerable between-study heterogeneity was present (Chi^2 : 132.68, df: 13, $P < 0.0001$; I^2 : 90.2%; τ^2 : 0.0092) (Figure 4).

When all complications were considered together, the overall complication rate was 3.3% (44/1,318) in the ultrasound-guided group and 5% (160/3,190) in the non-ultrasound-guided group. This is slightly lower with ultrasound guidance, but the difference did not reach statistical significance (OR: 0.76, $P = 0.11$). Overall, the pooled findings suggest that ultrasound guidance primarily improves technical success and reduces the risk of major complications, whereas minor complication rates remain similar between techniques.

The substantial heterogeneity observed across studies may be attributed to multiple reasons, including differences in puncture site and technique, variance in sample sizes, differences in study design and quality, heterogeneous follow-up durations, and geographical and temporal variation.

The certainty of evidence assessed using GRADE was very low for technical success and minor complications and low for major complications. All outcomes were downgraded for risk of bias because the evidence was derived predominantly from retrospective observational studies. Minor complications were additionally downgraded for imprecision because of the spread of CIs across the line of no effect.

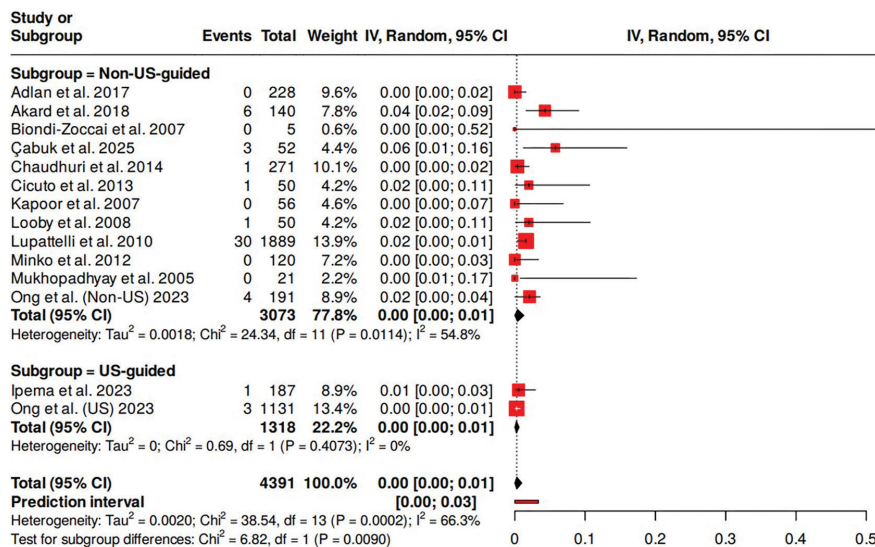


Figure 3. Forest plot of 13 studies, including 4,391 access closures, for major complication rates. CI, confidence interval; US, ultrasound.

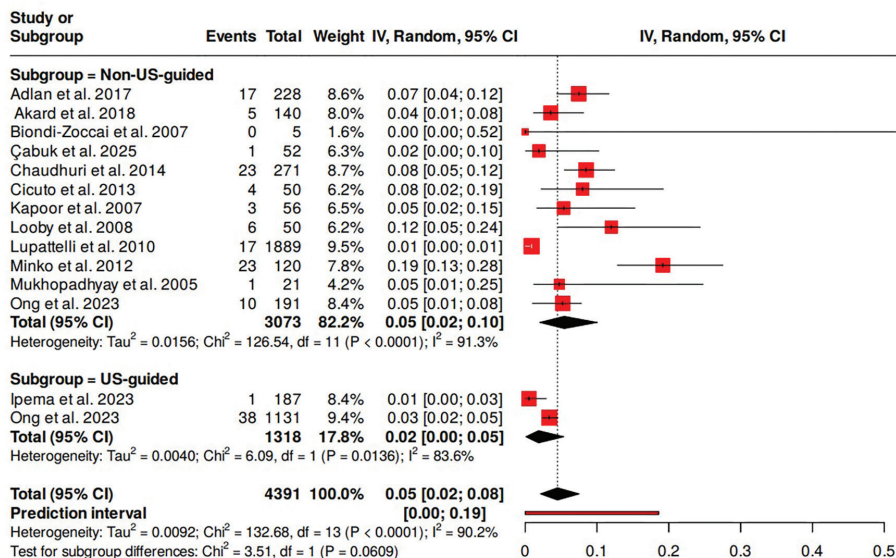


Figure 4. Forest plot of 13 studies, including 4,391 access closures, for minor complication rates. CI, confidence interval; US, ultrasound.

Discussion

Antegrade femoral artery access poses distinct anatomical and technical challenges compared with retrograde access, contributing to higher complication rates.²⁶ The trajectory of antegrade puncture is typically more acute, and the puncture site is often located more distally, where vessel calcification and atherosclerotic disease are more prevalent.²⁷ Furthermore, antegrade access frequently occurs in patients with CLI or severe peripheral arterial disease, representing a higher-risk population with compromised

vascular anatomy. The increased technical difficulty of antegrade puncture, combined with more challenging vascular anatomy and higher-risk patient profiles, necessitates strategies to minimize closure device-related complications in this setting.

Complications related to VCDs impose a notable clinical and economic burden, frequently necessitating hospital readmission and reintervention.²⁸ Access-site complications following percutaneous procedures can prolong hospital stay or cause readmission, with major complications such as pseudoaneurysm, arterial occlusion, and significant hematoma requiring surgical

repair, thrombin injection, or prolonged compression therapy.²⁹ Studies have shown that device-related complications increase healthcare costs by more than USD 5,000 per patient and extend hospital length of stay by 2–4 days.³⁰ Real-time ultrasound guidance has been shown to enhance technical success rates and reduce complications in both retrograde and antegrade femoral artery punctures with multiple closure devices, including Angio-Seal,^{6,10} Perclose ProGlide,¹⁴ and StarClose.¹⁵ Specifically, for Angio-Seal deployment, ultrasound guidance enables the precise visualization of the arterial puncture site, confirmation of the appropriate vessel diameter, exclusion of posterior wall injury, and the real-time monitoring of anchor deployment within the vessel lumen, thereby optimizing device positioning and reducing the risk of maldeployment.^{6,10,16} These technical advantages translate directly into reduced complication rates and improved procedural outcomes.

The findings of this meta-analysis indicate that ultrasound guidance is associated with higher technical success rates and the reduced risk of major complications in antegrade Angio-Seal closure. The pooled major complication rate in the ultrasound-guided group was 0.3%, compared with 1.5% in the non-ultrasound-guided group (OR: 0.20, $P < 0.001$). It is important to note that the largest study contributing to the non-ultrasound-guided pool, that by Lupattelli et al.²⁴ ($n = 1,889$), employed specific exclusion criteria for femoral puncture and Angio-Seal placement, including a vessel diameter of < 5 mm, severe calcification, and a puncture site > 1 cm below the femoral bifurcation, which likely contributed to their relatively low complication rate of 1.9%. By contrast, the study by Minko et al.⁵ reported a lower technical success rate of 92.1% in the same group because no exclusion criteria for Angio-Seal usage were applied; the technical failures were primarily attributable to sheath kinking in difficult groins with acute angulation, which precluded safe transfer of the Angio-Seal footplate to the puncture vessel for guided closure.

A systematic review by Kennedy et al.⁹ of antegrade VCDs use reported pooled complication rates of 4.6% across all device types in antegrade access. Our meta-analysis, focused specifically on antegrade Angio-Seal deployment, demonstrates an overall major complication rate of 1.14%, substantially lower than the previously reported rates for mixed device types. This suggests

that Angio-Seal may offer advantages for antegrade closure, possibly related to its anchor-and-collagen mechanism, which provides immediate hemostasis without requiring tissue approximation or suture-mediated closure. The ultrasound-guided subset in our analysis achieved an even more favorable complication rate of 0.3%, representing a nearly four-fold reduction compared with the overall pooled rate and an approximately fourteen-fold reduction compared with Kennedy's reported rate for all antegrade VCDs.

A primary limitation of this meta-analysis is the high level of statistical heterogeneity observed across the included studies, particularly for technical success (I^2 : 86%) and minor complications (I^2 : 90%). This degree of inconsistency likely reflects substantial clinical and methodological diversity within the existing literature. First, there was substantial variation in the patient population and techniques, with varying prevalence of diabetes, CLI, and other conditions; some studies used ultrasound for guidance; and some studies had specific inclusion and exclusion criteria for using Angio-Seal for closure, whereas others, such as that by Minko et al.,⁵ had no exclusion criteria. Although several studies applied anatomical or clinical selection criteria, these criteria determined whether Angio-Seal was used rather than whether ultrasound guidance was employed during closure. Additionally, the inclusion of studies spanning over two decades (2005–2025) could introduce temporal bias. Also, the reliance on retrospective cohort data across most of the studies increases the risk of selection bias and the inconsistent reporting of minor events, such as small hematomas. Since much of the pooled comparison is based on indirect comparisons between studies rather than on multiple head-to-head comparison studies, the observed associations cannot establish a strong causal benefit. Furthermore, follow-up assessment methods varied substantially; very few studies had patients followed up with ultrasound Doppler, with the majority relying on clinical examination alone or selective imaging based on clinical suspicion, potentially leading to the under-detection of asymptomatic complications. Cost considerations were not directly addressed in this meta-analysis due mainly to the unavailability of data and differences across centers.

In summary, this systematic review and meta-analysis demonstrates that ultrasound-guided Angio-Seal closure of antegrade femoral access is associated with a significant reduction in major access-related

complications and an improvement in technical success rates compared with non-ultrasound-guided closure. Specifically, the use of ultrasound guidance was associated with an 80% reduction in the odds of major complications (OR: 0.20, $P < 0.001$), suggesting a clear safety benefit in clinical practice.

The evidence regarding minor complications remains inconclusive, showing no statistically significant difference between the two approaches. The “very low” to “low” GRADE certainty of evidence, mainly driven by high statistical heterogeneity ($I^2 > 85\%$) and the retrospective and single-arm nature of most included studies, necessitates a cautious interpretation of these findings.

Future prospective, randomized controlled trials are required with standardized definitions of success and complications to further validate the long-term cost-effectiveness and safety of routine ultrasound guidance for VCDs.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Wagner J, Gandhi RT, Powell A. Technical approach to antegrade femoral access. *Tech Vasc Interv Radiol*. 2015;18(2):82-86. [\[Crossref\]](#) Erratum in: *Tech Vasc Interv Radiol*. 2015;18(4):285. Wager, Jaime [Corrected to Wagner, Jaime]. [\[Crossref\]](#)
2. Gutzeit A, Schoch E, Sautter T, Jenelten R, Graf N, Binkert CA. Antegrade access to the superficial femoral artery with ultrasound guidance: feasibility and safety. *J Vasc Interv Radiol*. 2010;21(10):1495-500. [\[Crossref\]](#)
3. Akard W, Cicuto K, Kim P, Mittleider D. Safety and efficacy of Angio-Seal closure in antegrade superficial femoral artery access. *Am J Interv Radiol*. 2018;2(3):1-7. [\[Crossref\]](#)
4. Alshehri AM, Elsharawy M. Comparison of AngioSeal and manual compression in patients undergoing transfemoral coronary and peripheral vascular interventional procedures. *Int J Angiol*. 2015;24(2):133-136. [\[Crossref\]](#)
5. Minko P, Katoh M, Gräber S, Buecker A. Obesity: an independent risk factor for insufficient hemostasis using the AngioSeal vascular closure device after antegrade puncture. *Cardiovasc Intervent Radiol*. 2012;35(4):775-778. [\[Crossref\]](#)
6. Ong DY, Yong E, Huang IKH, et al. The utility of ultrasound guidance to improve the safety of

closure of antegrade common femoral artery access after lower limb revascularization. *J Vasc Interv Radiol*. 2023;34(12):2208-2212. [\[Crossref\]](#)

7. Biondi-Zoccai GG, Fusaro M, Tashani A, et al. AngioSeal use after antegrade femoral arteriotomy in patients undergoing percutaneous revascularization for critical limb ischemia: a case series. *Int J Cardiol*. 2007;118(3):398-399. [\[Crossref\]](#)
8. Chaudhuri A, York A, Dey R. Percutaneous vascular closure using an anchored collagen plug provides effective haemostasis following both antegrade and retrograde femoral arterial punctures. *Eur J Vasc Endovasc Surg*. 2014;48(2):220-225. [\[Crossref\]](#)
9. Kennedy SA, Rajan DK, Bassett P, Tan KT, Jaber A, Mafeld S. Complication rates associated with antegrade use of vascular closure devices: a systematic review and pooled analysis. *J Vasc Surg*. 2021;73(2):722-730.e1. [\[Crossref\]](#)
10. Ipema J, de la Mar ACJ, Betman MJC, et al. Ultrasound-assisted Angio-Seal VIP closure of antegrade femoral access following lower extremity endovascular interventions. *J Crit Limb Ischem*. 2023;3(1):E1-E5. [\[Crossref\]](#)
11. Seto AH, Abu-Fadel MS, Sparling JM, et al. Real-time ultrasound guidance facilitates femoral arterial access and reduces vascular complications: FAUST (Femoral Arterial Access With Ultrasound Trial). *JACC Cardiovasc Interv*. 2010;3(7):751-758. [\[Crossref\]](#)
12. d'Entremont MA, Alrashidi S, Alansari O, et al. Ultrasound-guided femoral access in patients with vascular closure devices: a prespecified analysis of the randomised UNIVERSAL trial. *EuroIntervention*. 2023;19(1):73-79. [\[Crossref\]](#)
13. Huang YC, Lu YH, Ting WY. Ultrasound-guided vs. non-ultrasound-guided femoral artery puncture techniques: a comprehensive systematic review and meta-analysis. *Ultrasound J*. 2025;17(1):19. [\[Crossref\]](#)
14. Ross DS, Nogic J, Cong H, et al. Ultrasound-guided deployment of ProGlide™ device in transfemoral transcatheter aortic valve implantation and risk reduction of vascular complications: a propensity-matched cohort study. *Catheter Cardiovasc Interv*. 2024;103(5):771-781. [\[Crossref\]](#)
15. Puckridge PJ, Spark JI, Thompson W. The use of ultrasound to assist deployment of the StarClose vascular closure device in arterial access sites. *Eur J Vasc Endovasc Surg*. 2009;38(1):88-90. [\[Crossref\]](#)
16. Groenewegen FA, Charehbili A, Panfilov IA, et al. Ultrasound-guided vs non-ultrasound-guided Angio-Seal vascular hemostasis after endovascular treatment for peripheral artery disease: an observational study. *J Endovasc Ther*. 2026;33(3):1383-1395. [\[Crossref\]](#)
17. Adlan T, Shahin Y, Kember P, Isaacs J, Seymour R. Retrospective cohort study on Angio-

- Seal closure device safety and effectiveness in antegrade superficial femoral artery punctures: a comparison with antegrade common femoral artery punctures. *Int J Surg.* 2017;48:225-227. [\[Crossref\]](#)
18. Cicuto K, Mittleider D, Kim P. Safety and efficacy of the Angio-Seal closure device with antegrade superficial femoral artery (SFA) access. *J Vasc Interv Radiol.* 2013;24(4 Suppl):S118. [\[Crossref\]](#)
 19. Kapoor B, Panu A, Berscheid B. Angio-Seal in antegrade endovascular interventions: technical success and complications in a 55-patient series. *J Endovasc Ther.* 2007;14(3):382-386. [\[Crossref\]](#)
 20. Looby S, Keeling AN, McErlean A, Given MF, Geoghegan T, Lee MJ. Efficacy and safety of the angioseal vascular closure device post antegrade puncture. *Cardiovasc Intervent Radiol.* 2008;31(3):558-562. [\[Crossref\]](#)
 21. Modi S, Gadvi R, Babu S. Initial experience with Angioseal™: safety and efficacy of the endovascular closure device. *Indian J Radiol Imaging.* 2013;23(2):134-138. [\[Crossref\]](#)
 22. Mukhopadhyay K, Puckett MA, Roobottom CA. Efficacy and complications of Angioseal in antegrade puncture. *Eur J Radiol.* 2005;56(3):409-412. [\[Crossref\]](#)
 23. Reekers JA, Müller-Hülsbeck S, Libicher M, et al. CIRSE vascular closure device registry. *Cardiovasc Intervent Radiol.* 2011;34(1):50-53. [\[Crossref\]](#)
 24. Lupattelli T, Tannouri F, Garaci FG, et al. Efficacy and safety of antegrade common femoral artery access closure using the Angio-Seal device: experience with 1889 interventions for critical limb ischemia in diabetic patients. *J Endovasc Ther.* 2010;17(3):366-375. [\[Crossref\]](#)
 25. Çabuk G, Çabuk AK. Efficacy and safety of Angio-Seal™ VIP vascular closure device compared to manual compression for access site hemostasis in patients who underwent antegrade common femoral artery puncture for popliteal and/or below the knee intervention. *Turk J Clin Lab.* 2025;16(2):240-245. [\[Crossref\]](#)
 26. Wheatley BJ, Mansour MA, Grossman PM, et al. Complication rates for percutaneous lower extremity arterial antegrade access. *Arch Surg.* 2011;146(4):432-435. [\[Crossref\]](#)
 27. Pezold M, Blumberg S, Sadek M, et al. Antegrade superficial femoral artery access for lower extremity arterial disease is safe and effective in the outpatient setting. *Ann Vasc Surg.* 2021;72:175-181. [\[Crossref\]](#)
 28. Bangalore S, Arora N, Resnic FS. Vascular closure device failure: frequency and implications: a propensity-matched analysis. *Circ Cardiovasc Interv.* 2009;2(6):549-556. [\[Crossref\]](#)
 29. Biancari F, D'Andrea V, Di Marco C, Savino G, Tiozzo V, Catania A. Meta-analysis of randomized trials on the efficacy of vascular closure devices after diagnostic angiography and angioplasty. *Am Heart J.* 2010;159(4):518-531. [\[Crossref\]](#)
 30. Amin AP, Pinto D, House JA, et al. Association of Same-day discharge after elective percutaneous coronary intervention in the United States with costs and outcomes. *JAMA Cardiol.* 2018;3(11):1041-1049. [\[Crossref\]](#)