0003-4975
https://doi.org/10.1016/j.athoracsur.2026.03.077

INVITED EXPERT REVIEW

Acute Distal Limb Ischemia After Large-Bore Arterial Access: An Expert Review and Consensus Recommendations

Raghad Said, MD,[1,*] Michael P. W. Grocott, MD,[2,*] Courtney Maxey-Jones, MD,[3,4,5] Allen D. Hamdan, MD,[6] Jerome Crowley, MD,[7] Scott Brudney, MD,[8] Eric Kaiser, MD,[9] Brian Weiss, MD,[10] Balaram Anandamurthy, MD,[9,11] and Daniel T. Engelman, MD[12]

ABSTRACT

BACKGROUND Although large-bore arterial access (LBAA) enables lifesaving structural heart interventions and mechanical circulatory support, it increases patients' risk of acute distal limb ischemia (ADLI). Morbidity includes the potential need for fasciotomy or amputation, prolonged hospitalization, and death, yet practice patterns remain variable across centers. This consensus statement by multidisciplinary experts aims to define ADLI in the context of LBAA and to standardize best practices.

METHODS A 1-day consensus conference was convened with experts in critical care, anesthesiology, interventional cardiology, and vascular and cardiac surgery. A premeeting literature synthesis framed priority questions on physiology, prevention, detection, and management. Draft statements were refined through plenary and breakout sessions, finalized by recorded vote, and confirmed by the entire panel. Meeting transcripts and notes informed the narrative rationales.

RESULTS Consensus was reached on a definition, 3 consensus statements, and 18 recommendations regarding ADLI after LBAA. Core elements were standardized prevention and monitoring standards, ultrasound-guided common femoral anterior wall puncture above the bifurcation by trained operators, a documented baseline neurovascular examination followed by at least hourly reassessment, consideration of near-infrared tissue oximetry for continuous trend monitoring, anticoagulation according to institutional protocols, and early vascular surgery engagement with predefined escalation and transfer criteria. For patients supported by centrifugal pumps, a prophylactic distal perfusion cannula with hourly flow checks is recommended. The resulting algorithms emphasize early trend recognition and rapid reperfusion.

CONCLUSIONS This expert review provides minimum standards and consensus recommendations to shorten recognition-to-action time and improve limb salvage, thereby supporting quality improvement and multicenter learning.

(Ann Thorac Surg 2026;■:■-■)

*Drs Said and Grocott contributed equally to this work.

This document was reviewed and formally endorsed by the ERAS® Cardiac International Society following independent evaluation by its Executive Committee.

Presented at the Sixty-second Annual Meeting of The Society of Thoracic Surgeons, New Orleans, LA, Jan 29-Feb 1, 2026.

[1]Department of Internal Medicine, Hackensack University Medical Center, Hackensack, New Jersey; [2]National Institute for Health and Care Research (NIHR) Southampton Biomedical Research Centre, University Hospital Southampton, University of Southampton, Southampton, United Kingdom; [3]CNY Medical Services, Baldwinsville, New York; [4]Heart and Vascular Institute, United Health Services (UHS)-Wilson Hospital, Johnson City, New York; [5]Department of Medicine, State University of New York (SUNY) Upstate University Hospital, Syracuse, New York; [6]Department of Surgery, Beth Israel Deaconess Medical Center, Boston, Massachusetts; [7]Department of Anesthesia, Critical Care, and Pain Medicine, Massachusetts General Hospital, Boston, Massachusetts; [8]Department of Anesthesia, Max Rady College of Medicine, University of Manitoba, Winnipeg, Manitoba, Canada; [9]Department of Cardiothoracic Anesthesiology, Cleveland Clinic, Cleveland, Ohio; [10]Department of Anesthesiology and Perioperative Medicine, Thomas Jefferson University, Philadelphia, Pennsylvania; [11]Department of Surgical Critical Care, Integrated Hospital Care Institute, Cleveland Clinic, Cleveland, Ohio; and [12]Department of Surgery, Heart and Vascular Program, Baystate Health and University of Massachusetts Chan Medical School-Baystate, Springfield, Massachusetts

Address correspondence to Dr Said, Hackensack University Medical Center, 30 Prospect Ave, Hackensack, NJ 07601; email: saidmd07@yahoo.com.

Abbreviations and Acronyms

ABI = ankle–brachial index
ADLI = acute distal limb ischemia
CFA = common femoral artery
DPC = distal perfusion cannula
ECMO = extracorporeal membrane oxygenation
LBAA = large-bore arterial access
MCS = mechanical circulatory support
NIRS = near-infrared spectroscopy
PFA = profunda femoris artery

Large-bore arterial access (LBAA) enables a range of endovascular procedures, including peripheral interventions, transcatheter aortic valve replacement, and provision of mechanical circulatory support (MCS). LBAA is commonly defined as involving a catheter diameter >8F (2.67 mm)[1,2] and facilitates lifesaving interventions such as extracorporeal membrane oxygenation (ECMO).[1] Acute distal limb ischemia (ADLI) is a common complication of these procedures and may result in limb loss, prolonged hospitalization, increased costs, and mortality.[3,4] Given the heterogeneity in patient presentation, procedural complexity, and variability in institutional and operator expertise, standardization remains challenging.

This expert review discusses ADLI in the context of LBAA, encompassing (1) its definition, pathogenesis, and risk factors and (2) best practices for its prevention, detection, monitoring, and management.

MATERIAL AND METHODS

Preparatory work included a literature review, gap analysis, and circulation of draft questions. Searches were conducted in PubMed, Embase, Cochrane Library, Trip Database, Semantic Scholar, ClinicalTrials.gov, World Health Organization International Clinical Trials Registry Platform, *Circulation*, European Society for Vascular Surgery Guidelines Portal, *Journal of Vascular Surgery*, Society of Interventional Radiology, *Arteriosclerosis, Thrombosis, and Vascular Biology*, Radiological Society of North America Case Collection, and PubMed Central.

A 1-day multidisciplinary consensus conference was convened on March 27, 2025 involving experts in MCS and critical illness, including vascular surgeons, cardiac surgeons, anesthesiologists, cardiologists, and critical care specialists. The lead authors (R.S., D.E., J.C.) presented syntheses on ADLI physiology, prevention, detection, and management. Participants then joined breakout sessions, structured to ensure balanced professional representation, to refine draft statements and identify areas of agreement and uncertainty. Consensus statements and recommendations were finalized through iterative discussion in plenary and breakout sessions, formal voting, and postmeeting refinement through Microsoft Teams. Final approval was confirmed by unanimous email agreement.

Conference proceedings were recorded and transcribed. ChatGPT-4o summarized the transcript on April 20, 2025 by using a standardized prompt. The summary and contemporaneous faculty notes informed commentary for each statement, which authors (R.S., D.E., A.H., M.G.) edited for clarity and completeness. All authors met International Committee of Medical Journal Editors criteria and served as guarantors. The conference was supported by J&J MedTech Heart Recovery, Danvers, Massachusetts, USA. Professional manuscript writing and editing assistance were supported by the ERAS Cardiac International Society.

RESULTS

This process yielded 3 consensus statements and 18 recommendations addressing the clinical presentation, prevention, identification, and management of ADLI, along with a summary of key elements of its pathogenesis. Consensus statements reflect overarching principles derived from the panel's agreement on definitions and core concepts, whereas recommendations represent actionable practice directives intended for implementation at the bedside or institutional level.

CONSENSUS STATEMENTS

Statement 1: ADLI is defined as a sudden onset reduction in blood flow to the limb resulting in inadequate delivery of oxygen and nutrients to meet the metabolic demands of the tissues.[5-8] The term *threatened limb* is often used when the diagnosis is raised.[5,8]

ADLI results from inadequate limb perfusion that fails to meet tissue metabolic needs.[8] Its sequelae range from subclinical deficits to irreversible ischemia and limb loss.[8,9] In LBAA, ischemia typically occurs distal to the access site, precipitated by thrombosis, embolism, or mechanical obstruction. Onset is typically sudden, within minutes to hours, but can be delayed by hemodynamic changes or new thrombus or embolus formation at the access site.[8,9] Clinical

TABLE 1 Patient-Related Factors Contributing to ADLI

Factor	Contribution to ADLI
Peripheral artery disease	Baseline arterial inflow is reduced, increasing vulnerability to further flow compromise from large-bore cannulas.[3,6,20]
Female sex	Females may have smaller vessel diameters, potentially increasing degree of flow obstruction relative to cannula size.[3,21,22]
Poorly controlled type 2 diabetes	Associated with peripheral artery disease and microvascular disease, both risk factors for ADLI.[23]
Obesity, BMI ≥30 kg/m^2	Greater tissue mass and metabolic demand may increase supply-demand mismatch[24]; vascular access and DPC placement are often more challenging.
BMI <18.5 kg/m^2	Associated with smaller vessels and limited collateral flow.[25]
Anemia	Reduced oxygen-carrying capacity can worsen ischemia under low-flow settings.[26]
High venous or right-sided pressures	Impede venous outflow, reducing the perfusion gradient.[17]
Prior vascular procedures or radiation	May distort vascular anatomy or impair collateral flow.[27]
Raynaud phenomenon	Vasospastic tendency may predispose to arterial spasm after cannulation.[28]
Age	Advanced age correlates with higher vascular disease prevalence.[29]
Race and ethnicity	African American and Hispanic ethnicity may confer higher risk.[30]

ADLI, acute distal limb ischemia; BMI, body mass index; DPC, distal perfusion cannula.

features range from transient symptoms to critical ischemia with permanent damage and possible amputation.[10] The risk period begins at arterial cannulation and extends beyond cannula removal (see Recommendation 18).[11] A suspected case is termed a *threatened limb*, underscoring the need for urgent evaluation,[8] and all limbs with LBAA should be considered at risk.

ADLI PATHOGENESIS. Limb perfusion distal to LBAA reflects an interplay of 5 domains:

1. Arterial flow: Delivery depends on adequate cardiac output and the condition of the arteries; flow can be reduced by extrinsic compression, large-bore cannulas, thrombus, small or diseased vessels, access-related complications (eg, dissection flaps), and low-flow states that promote cannula-associated thrombosis.[12,13]
2. Microvascular perfusion: Effective capillary autoregulation is disrupted by shock, sepsis, high-dose vasopressors, and microemboli originating from the cannula or vessel wall.[14,15]
3. Interstitial pressure: Rising compartment pressures impede microvascular flow and tissue perfusion,[16] most commonly in the calf but occasionally in the thigh.
4. Elevated venous pressures or insufficiency: Venous outflow obstruction (especially with concurrent large-bore venous access) can reduce the arteriovenous gradient, foster edema, raise interstitial pressure, and limit perfusion; poor lymphatic clearance further worsens fluid accumulation.[17]

TABLE 2 Procedural Factors Contributing to ADLI

Factor	Contribution to ADLI
Large cannula size relative to vessel diameter and BSA	Larger cannulas cause greater mechanical obstruction, especially in smaller vessels; considering the BSA-cannula size ratio may help prevent injury.[13,31,32]
Access site	Cannulation near or across bifurcations (eg, profunda femoris origin) increases complication risk.[32-34]
Technical difficulty of insertion	Multiple punctures raise risk of vessel injury, dissection, and thrombosis.[3,35] Posterior wall puncture should be avoided.[36]
Arterial spasm	Mechanical irritation from the cannula or vasoactive medications can trigger spasm, reducing distal flow.[37]
Thrombosis or embolization	Thrombus formation around the cannula sheath and plaque dislodgement can cause acute limb ischemia. Macroemboli and microemboli are potential complications.[3]

ADLI, acute distal limb ischemia; BSA, body surface area.

TABLE 3 Clinical Factors Contributing to ADLI

Factor	Contribution to ADLI
Shock states	Hypoperfusion in shock can independently compromise limb perfusion.[9,38] Microvascular dysfunction and high-dose vasopressors can further elevate ADLI risk.[38]
High-dose vasopressors	Maintain systemic blood pressure but can cause peripheral vasoconstriction, potentially worsening ischemia.[9,38]
Anticoagulation or antiplatelet therapy	Prevents thrombosis but raises bleeding risk at the access site, potentially necessitating interventions that impair distal flow.[39,40]
Compartment syndrome	Elevated tissue pressure can impair microvascular perfusion, especially in patients with large muscle burden; reperfusion-related edema can exacerbate injury.[19,41]
Reperfusion injury after device removal	Limb reperfusion can trigger oxidative stress, edema, inflammatory cell influx, and microvascular damage, increasing risk of compartment syndrome, irreversible tissue damage, amputation, and systemic complications.[19,42] Vigilant monitoring for 2-12 hours after removal is critical to detecting delayed compartment syndrome.

ADLI, acute distal limb ischemia.

5. Tissue metabolism: When oxygen demand exceeds delivery; for example, sepsis can increase oxygen requirements.[18]

In summary, ADLI etiology in critical illness is multifactorial, reflecting the interaction of patient, procedural, and clinical variables. A system-level view of perfusion, metabolism, and fluid clearance helps estimate risk.

Statement 2: ADLI is a medical emergency.

ADLI is a limb-threatening and potentially life-threatening medical emergency that requires urgent, systematic, and multidisciplinary management. ADLI commonly arises after the insertion of large-bore femoral arterial cannulas for MCS or other interventions. Thus, the presence of a large cannula in the femoral artery in itself poses a baseline risk for ADLI.[3,14,19]

Statement 3: ADLI can occur in any patient due to various physiologic insults and risk factors, and understanding these processes is crucial for managing ischemia and reperfusion injury. Limb ischemia risk persists throughout the duration of large-bore arterial cannulation and during the subsequent removal period.

Regarding patient-, procedure-, and clinical context-related risk factors contributing to ADLI (Tables 1,[20-30] 2,[31-37] and 3,[38-42] respectively), individuals at higher risk of ADLI after LBAA require needs-based surveillance and targeted preventive measures. Nevertheless, any femoral large-bore cannula confers baseline risk, so universal prevention and monitoring are essential, with heightened vigilance when risk factors are present.[43]

Risk scores can aid triage and monitoring but vary in purpose and validation. The Cannula-Associated Limb Ischemia Severity Score, derived from femoral venoarterial ECMO, estimates risk and the need for distal perfusion cannula placement during large-bore access.[44] The Rutherford acute limb ischemia classification stages limbs as viable, threatened, or irreversible. Although it is not an incident risk score, it guides urgency and helps predict outcomes once ADLI occurs.[5,45,46]

On the basis of these overarching principles, the panel developed 18 implementation-focused recommendations.

RECOMMENDATIONS

Recommendation 1: The prevention, diagnosis, and treatment of ADLI should be managed by a multidisciplinary team supported by a codeveloped algorithm.

To ensure a rapid, effective, and reliable response to this medical emergency, developing and implementing an institution-based ADLI prevention, diagnosis, and management algorithm is recommended. This algorithm should include a standardized framework to enable early recognition of ADLI and trigger prompt, effective management strategies aimed at improving patient outcomes.[3,19,30]

Recommendation 2: Perform a baseline clinical assessment with clear documentation before insertion of a large-bore catheter.

Identifying patient-, procedure-, and clinical context-related risk factors requires a thorough baseline clinical assessment with clear documentation to ensure effective continuity of subsequent care.[3,47]

Recommendation 3: Before the procedure, assess vascular anatomy to establish an anatomic baseline and inform selection of the optimal access site.

Preprocedural anatomic assessment and planning may encompass the following techniques:

- *Review of previous imaging*: Before LBAA, any available vascular imaging (eg, computed tomographic angiography, magnetic resonance angiography, prior noninvasive arterial studies) should be reviewed to assess vessel size, anatomy, presence of plaques or calcifications, and collateral flow.
- *Vascular ultrasound assessment*: When possible, a preprocedural ultrasound assessment of the femoral artery should be performed to measure vessel diameter, evaluate patency, and identify any thrombus or significant atherosclerotic disease. Ultrasonography can also aid in identifying the optimal puncture site, ideally in the common femoral artery (CFA) above the bifurcation of the superficial femoral artery and profunda femoris artery (PFA).[47]
- *Ankle-brachial index (ABI):* Even in emergency situations, consider obtaining an ABI before insertion to provide a baseline assessment of peripheral perfusion.[30]

Recommendation 4: Carefully consider cannula size and location to achieve the desired level of support.

Cannula size selection should prioritize the smallest arterial cannula capable of achieving the intended level of circulatory support while minimizing distal flow obstruction. When feasible, CFA caliber and disease burden should be assessed preprocedurally, using ultrasound or available cross-sectional imaging. Cannula oversizing should be avoided in borderline vessels, particularly in patients with peripheral artery disease, smaller body size, or limited collateral circulation, because cannula-to-vessel mismatch is a major contributor to distal hypoperfusion. Escalation to larger cannulas should be treated as a dynamic increase in ADLI risk, prompting heightened surveillance and consideration of prophylactic distal perfusion strategies. Institutional protocols should incorporate a standardized approach to cannula selection that integrates vessel diameter, anticipated flow requirements, and device-specific performance targets. Careful consideration of the cannula size and the risk of complications is essential. Patient body size, vessel diameter, and downstream tissue metabolic burden are all important factors to consider when selecting a cannula size and access site.[14]

Recommendation 5: Adhere to published standards of care when performing LBAA.[19,43,47-49]

Optimal access techniques depend on operator expertise and training, the use of relevant bedside imaging techniques (eg, ultrasonography), and careful selection of the cannulation site.

- *Operator expertise and training*: The most skilled operator available should perform ultrasound-guided access. Formal training in wire and cannulation techniques is essential for all individuals performing these procedures to ensure standardization of procedural conduct.[19,50]
- *Ultrasound-guided access:* Routine use of ultrasound guidance for all LBAA is strongly encouraged. Ultrasonography improves the accuracy of vessel puncture, reduces the number of attempts, and minimizes the risk of posterior wall puncture and other mechanical complications.[51,52]
- *Optimal puncture site selection:* Puncture of the anterior wall of the CFA should avoid the femoral bifurcation to minimize the risk of occluding or injuring the PFA, a critical source of collateral flow.[53,54] Care should also be taken to avoid puncture above the inguinal ligament, using the top of the femoral head as a standard landmark. When puncture is performed in a fluoroscopy suite, an image of the micropuncture needle should be evaluated and stored for future reference.
- *Vasodilators* (eg, intraarterial nitroglycerin, verapamil) may be considered during insertion in high-risk or vasospastic patients.[55,56]

Recommendation 6: When possible, avoid performing LBAA in the same limb as a large-bore venous access site.

Avoid ipsilateral cannulation because large-bore arterial and venous access in the same limb can compromise arterial inflow, venous outflow, and overall limb perfusion. Additionally, large-bore arterial cannulation should be avoided in a limb with a dialysis catheter because dialysis access alters flow and makes patients prone to thrombosis.[57-59] Moreover, dialysis catheters are generally easier to relocate, with fewer vascular consequences.[59]

Recommendation 7: Implement immediate and continuous monitoring throughout LBAA, from insertion to removal, to ensure early identification and timely management of ADLI.

Early detection of ADLI is critical. To ensure the best patient outcomes, any concerning signs should be relayed immediately to the treating physician to determine whether escalation is warranted.[58] Obtain and document a baseline limb examination before LBAA, including the 5 Ps (pain, pulses, pallor, paresthesia, and paralysis), to enable reliable comparison if ADLI is suspected.[19] Maintain a high index of suspicion for compartment syndrome, particularly in patients with large muscle mass or marked swelling. Disproportionate pain, tense compartments, and pain with passive stretch are key red flags.[41] Support serial clinical examinations with objective measures such as Doppler ultrasonography for distal pulses and flow, and serial ABI to monitor perfusion in patients without known peripheral artery disease, noting that ABI is less reliable immediately after the procedure and in patients with significant edema.[19] When available, continuous methods such as near-infrared spectroscopy (NIRS) can aid early trend detection. Ensure that the baseline examination and expectations are communicated to the nursing and resident teams, with escalation criteria established at the time of LBAA insertion.

Recommendation 8: Conduct a neurovascular examination at least hourly after insertion.

A thorough neurovascular examination of the affected limb should be performed and documented before LBAA begins and at least once per hour after insertion. More frequent assessments (eg, every 15-30 minutes initially) are warranted in the early postprocedural period or in patients with any signs or symptoms of concern. The initial assessment should specifically evaluate for the 5 Ps, and any new or worsening neurologic abnormality (eg, paresthesia, weakness) should prompt immediate reassessment.[14]

Recommendation 9: Monitoring with noninvasive tissue oximetry should be considered when a large-bore access catheter is inserted.

Monitoring with NIRS should be strongly considered in all patients with LBAA in situ. NIRS provides continuous, real-time assessment of regional tissue oxygen saturation in skeletal muscle. Although absolute NIRS values can vary, sustained changes (>4 minutes) are more clinically significant. Trends in NIRS values should be closely monitored,[60-62] and any of the following findings should raise concern: a sustained absolute NIRS value <50%, a relative decrease of >15% from baseline, or a difference from the contralateral limb of >20%. This modality may be particularly important in nonawake or altered patients.

Recommendation 10: Sole reliance on laboratory markers to exclude ADLI should be avoided.

Diagnosis and staging of ADLI should be based on clinical assessment. Serum lactate, creatine kinase, and myoglobin levels are nonspecific and typically rise after significant tissue injury. Normal values must not delay evaluation or treatment.[19,63]

Recommendation 11: Administer the institution's standard anticoagulation protocol to minimize thromboembolic events.

Institutional standards of care for anticoagulation should be followed to minimize the risk of thrombus formation around the cannula. In patients already receiving antiplatelet or anticoagulant medications, a careful risk-benefit assessment should be performed to balance the need for anticoagulation for the primary intervention against the potential for bleeding complications at the access site.[3,60]

DISTAL PERFUSION CANNULA. Placing a distal perfusion cannula (DPC) (Figure[64]) is a preventative and therapeutic strategy to mitigate ADLI risk in patients undergoing LBAA, particularly when flow is expected to be significantly impeded or ischemic signs develop. If needed, DPCs should be inserted near the LBAA site to facilitate vascular cutdown and embolectomy. The distal tip should be positioned as far distally as possible within the superficial femoral artery to maximize lower extremity perfusion and reduce risk to the PFA. DPC size should be selected on the basis of the downstream tissue mass requiring perfusion rather than vessel size, with catheter length adjusted for patients with obesity or large, muscular limbs. A functioning DPC does not eliminate ischemia risk because thrombosis and flow stagnation can still occur.[14,61]

Recommendation 12: In patients supported **by a centrifugal pump (eg, patients on ECMO), the DPC should be placed at the time of large-bore femoral arterial access.**

In patients connected to an external centrifugal pump (eg, CentriMag [Abbott], TandemHeart [LivaNova]) through LBAA, a DPC should be placed prophylactically at the time of initial access. The centrifugal pump can significantly reduce distal flow, making DPC placement vital for maintaining adequate perfusion to the lower extremity.[60,61]

Recommendation 13: Confirm and monitor DPC flow using an inline flowmeter at least hourly, aiming for a target flow of >100 mL/min.

DPC flow should be confirmed immediately after placement and then monitored at least hourly, targeting a flow rate of >100 mL/min.[60,61,65] The catheter should be inspected for kinks, air, and thrombus and should be repositioned or upsized as needed. Flow rates below the threshold without clinical changes or signs should be monitored more frequently.

Recommendation 14: Even with a functioning DPC, ADLI may still occur, necessitating continued comprehensive monitoring.

The presence of a functioning DPC does not preclude the development of ADLI. Flow stasis can occur in the segment of the native artery between the LBAA cannula and the DPC inflow, potentially leading to thrombus formation and distal embolization. Therefore, even with a DPC in place, vigilant monitoring for signs of ADLI remains essential.[14,61]

Recommendation 15: Timely intervention in patients who develop ADLI is critical. This intervention includes emergency consultation with a vascular surgeon, concurrent consideration of cannula removal, repositioning to an alternative site, and possible transfer to a tertiary center via an established hub-and-spoke model.[3,19]

ADLI should be recognized and treated as a medical emergency.[19] A structured approach to the management of suspected or confirmed ADLI is essential to optimize limb salvage. Institutions should have clearly defined ADLI protocols that outline steps for evaluation, management, and escalation, including criteria for transfer to a center with more specialized vascular expertise.[3] *Immediate consultation with vascular surgery is essential once ADLI is suspected* (Table 4). Early involvement of vascular surgery expertise is critical for timely diagnosis and improves the likelihood of limb salvage.[3,19] A surgical intervention such as embolectomy, thrombectomy, or fasciotomy may be required promptly to restore limb perfusion and prevent irreversible tissue damage.[19] Interventional cardiology, interventional radiology, and cardiovascular surgery should be consulted as clinically indicated. Depending on the clinical scenario, and after discussion with the proceduralist, the cannula may be partially withdrawn, removed, or repositioned to optimize flow.[58,60] However, as noted previously, removing the cannula in these cases can lead to early or delayed compartment syndrome and/or embolization. Medical management may improve tissue perfusion and includes minimizing vasopressor use, administering vasodilators, and augmenting oxygen delivery to the limb.[58] In patients with suspected or observed arterial spasm, particularly during cannulation or when receiving high doses of vasopressors, administering

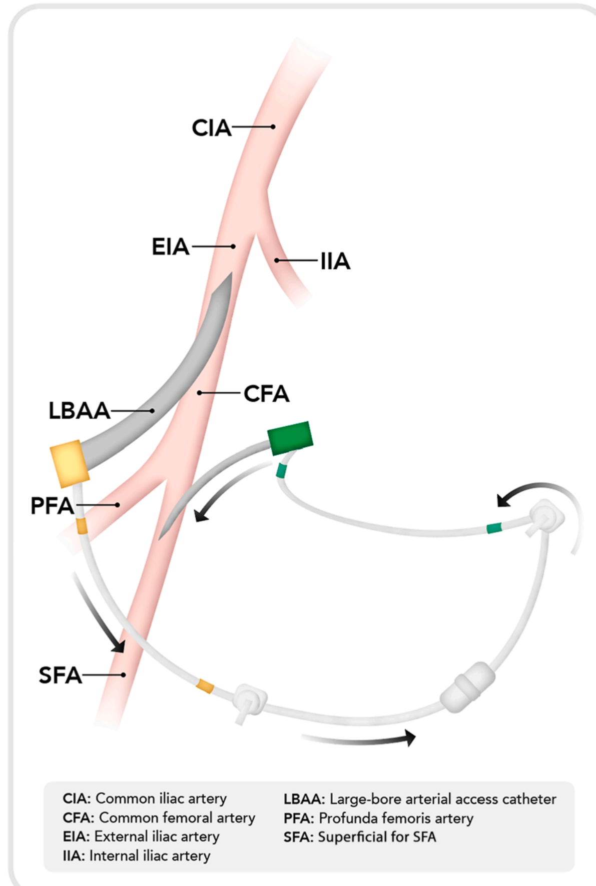

FIGURE A distal perfusion cannula. The arrows indicate the direction of the blood flow. Adapted from Lichaa.[64]

TABLE 4 Criteria for Vascular Surgery Consultation[a]

Category	Criteria	Consultation Approach
Emergency	• Acute change in pulse examination accompanied by clinical symptoms • Mottling, pallor, or marked limb coolness • New acute pain or neurologic change in an awake patient • Calf tightness or swelling suggesting compartment syndrome	Immediate consultation; do not delay for imaging
Urgent	• Loss or downgrade of pulse examination (eg, palpable pulse to Doppler-only) without overt ischemia • ≥20% decrease in near-infrared spectroscopy or drop in ankle-brachial index • Mild numbness on dorsal foot	Combined consultation with directed imaging (computed tomographic angiography or arterial duplex)

[a]Data derived from references 19, 30, and 60.

a systemic or targeted vasodilator such as intraarterial nitroglycerin or verapamil can be considered.

Transfer to a tertiary center with vascular surgery capabilities through an established hub-and-spoke system should be considered, particularly if local resources are insufficient to manage ADLI effectively.[60] It is also important to acknowledge the practical challenges of patient transfer in community hospital settings. When immediate transfer is not feasible, continued aggressive management within local capabilities is warranted, including close monitoring and consultation with local vascular surgery when available. If transfer to an accepting hub facility cannot be secured, consideration should be given to limiting services to align with available expertise.[3]

Recommendation 16: In patients with inadequate distal limb perfusion, therapeutic interventions to augment oxygen delivery should be implemented.

Strategies to increase systemic cardiac output, and thus arterial inflow to the limb, may be considered in consultation with the critical care team.[58] In anemic patients, optimizing oxygen-carrying capacity by raising the transfusion threshold may be considered, weighing the risks and benefits of transfusion.[60]

Recommendation 17: Patients with inadequate distal limb perfusion without an existing DPC *but with a centrifugal pump* require timely placement of a DPC.[60,61]

Recommendation 18: Removing an LBAA device does not eliminate the risk of subsequent or worsening ADLI, particularly in patients without a DPC, due to reperfusion injury, thrombus mobilization, or progression of compartment syndrome.[19,39]

Decannulation strategy should be standardized in institutional protocols and should account for access technique, device type, anticoagulation status, and local surgical and endovascular capabilities. When suture-mediated closure devices (eg, Perclose [Abbott]) are predeployed at the time of initial access, removal may be facilitated by percutaneous closure; however, clinicians should remain vigilant for thrombosis, embolization, or arterial stenosis at the access site.[66] In patients in whom preclosure was not performed, removal planning should include consideration of percutaneous closure, manual compression, or surgical cutdown, depending on cannula size, vessel anatomy, bleeding risk, and operator expertise. If percutaneous postclosure is attempted after a large-bore arterial device is removed, immediate availability of surgical expertise capable of performing operative cutdown and arterial repair is essential. Failed suture-mediated closure, device malfunction, arterial tear, occlusion, dissection, or uncontrolled bleeding can rapidly result in limb ischemia or hemodynamic instability. Centers should therefore ensure that removal of large-bore arterial cannulas, particularly those ≥14F to 16F or in patients with calcified or diseased vessels, is performed in an environment where conversion to open repair can be done without delay. This includes predefined escalation pathways, operating room access when indicated, and clear communication between interventional and surgical teams before decannulation. Regardless of closure technique, patients remain at risk for delayed ischemia, thrombus mobilization, reperfusion injury, and compartment syndrome after decannulation, underscoring the importance of continued neurovascular monitoring in the immediate postremoval period.

COMMENT

MISSION AND SCOPE. The goal of this consensus effort was to establish a practical, unified framework to prevent, detect, and manage ADLI after LBAA across hospital settings. This statement aims to standardize terminology, surveillance, objective triggers, anticoagulation pathways, device safeguards, and rapid escalation to shorten recognition-to-reperfusion time and improve limb salvage. The framework addresses minimum, auditable, simple, and scalable standards; defines core competencies, checklists, and transfer criteria; and proposes quality metrics to reduce variation and accelerate evidence generation.

IMPLEMENTATION GAPS THIS FRAMEWORK ADDRESSES. This consensus was developed in response to several recurring gaps observed across centers. These include inconsistent use of ultrasonography for common femoral access despite published evidence supporting improved safety, and delayed recognition-to-action driven by the absence of structured escalation pathways and limited access to vascular surgery and advanced imaging in some settings. Objective monitoring remains inconsistent, particularly regarding NIRS availability and interpretation; this framework emphasizes that management should rely on sustained trends and interlimb differences rather than isolated values. Devicerelated workflow issues also contribute to preventable harm, including inconsistent documentation and monitoring of DPC flow and the recognition that stasis between the cannula and distal perfusion cannula inflow can still promote thrombosis. Finally, anticoagulation strategies often require difficult trade-offs between thrombosis prevention and access-site bleeding, and this framework reinforces the need for institutional protocols that support both hemostasis and distal perfusion. These challenges are magnified in community settings, where transfer barriers and limited specialty availability make predefined hub-and-spoke escalation criteria particularly important.

EVIDENCE LIMITATIONS. The evidence base informing ADLI prevention and management remains limited because much of the literature is derived from single-center experiences, retrospective analyses, and device-specific reports. As a result, the strength of evidence supporting individual recommendations varies, particularly for prophylactic distal perfusion strategies and monitoring thresholds. The recommendations in this document should therefore be interpreted as consensus-based minimum safety standards grounded in pathophysiologic rationale and multidisciplinary clinical experience, while recognizing the need for higher-quality multicenter studies to refine and validate these practices.

STRENGTHS AND WEAKNESSES OF THE STUDY. This consensus was developed by a multidisciplinary team of surgeons, critical care specialists, anesthesiologists, and cardiologists. Strengths include a rigorous, literature-based process with iterative expert review and refinement. Limitations include the relatively small panel size and the absence of patient or public involvement, reflecting the technical complexity of the topic.

UNANSWERED QUESTIONS AND FUTURE RESEARCH. Despite growing awareness of ADLI, substantial knowledge gaps remain. Priorities for future investigation include developing validated risk prediction tools, defining optimal thresholds and workflows for continuous monitoring technologies such as tissue oximetry, and clarifying the pathophysiology of ischemia and reperfusion injury across different clinical phenotypes and device contexts. Additional work is needed to identify strategies that improve microvascular perfusion or reduce reperfusion injury, including evaluation of early biomarkers for subclinical ischemia. Future studies should also focus on optimizing cannula sizing, techniques for placing DPCs, and determining which institutional escalation pathways most reliably improve limb salvage and survival.

CONCLUSION. ADLI is a limb- and life-threatening complication of large-bore femoral arterial access that necessitates prompt, coordinated management. Prevention hinges on meticulous preprocedural assessment, ultrasound-guided access by experienced operators, adherence to anticoagulation and hemostasis best practices, and judicious use of prophylactic distal perfusion cannulas, particularly in patients requiring MCS. Early detection is key, requiring frequent bedside examinations and, where available, objective monitoring such as tissue oximetry. A structured response algorithm should be activated immediately, incorporating vascular surgery consultation, appropriate interventions, and timely transfer to a specialty center when needed. ADLI should be treated as a limb-threatening emergency requiring multidisciplinary collaboration to maximize limb salvage and improve outcomes.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the authors used ChatGPT-4o in order to summarize the conference proceedings transcript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

The authors wish to acknowledge JetPub Scientific Communications, LLC, who assisted the authors in the preparation of this manuscript, and Stephen N. Palmer, PhD, ELS, who provided editorial support.

FUNDING SOURCES

The conference was supported by J&J MedTech Heart Recovery.

DISCLOSURES

Raghad Said reports a relationship with Johnson & Johnson MedTech that includes: consulting and speaking. Michael P.W. Grocott reports funding support from the NIHR Southampton Biomedical Research Centre and the UK NIHR Senior Investigator Scheme; reports consulting and advisory board relationships with Becton Dickinson; reports prior advisory board relationships with Sphere Medical Ltd and South-West Sensors Ltd; and reports leadership involvement with the Perioperative Quality Initiative as Acting President. Courtney Maxey-Jones reports advisory and speaking relationships with Johnson & Johnson, Haemonetics, and AtriCure; reports advisory/investment involvement with Doctorpedia; and reports investment involvement with ROMTech. Allen D. Hamdan reports a consulting relationship with Johnson & Johnson. Jerome Crowley reports consulting for Johnson & Johnson. Scott Brudney reports a consulting relationship with Johnson & Johnson. Brian Weiss reports a consulting relationship with Johnson & Johnson. Balaram Anandamurthy reports a consulting relationship with Johnson &

Johnson. Daniel T. Engelman reports service on the device safety monitoring board for Edwards Lifesciences Transcatheter Valves; reports participation on executive steering committees for clinical trials sponsored by Alexion, Genentech, Bayer, and Chugai; and reports advisory board relationships with Medela, Arthrex, AtriCure, Johnson & Johnson, and Pharmacosmos. Eric Kaiser declares no conflicts of interest.

REFERENCES

1. Grant JK, Maniam A, Celli D, et al. Large-bore arterial access in the era of structural cardiovascular disease. *J Card Surg*. 2020;35:3088-3098. https://doi.org/10.1111/JOCS.14909

2. Pawlik AK, Rzeszutko Ł, Januszek R, et al. Hybrid method of large bore arterial access closure: single-center initial experience based on percutaneous coronary artery interventions assisted with left ventricle support device. *Cardiol J*. 2022;29:1040-1042. https://doi.org/10.5603/CJ.A2022.0096

3. Damluji AA, Tehrani B, Sinha SS, et al. Position statement on vascular access safety for percutaneous devices in AMI complicated by cardiogenic shock. *JACC Cardiovasc Interv*. 2022;15:2003-2019. https://doi.org/10.1016/j.jcin.2022.08.041

4. Guo M, Ji M, Qu J, Yuan C, Wang P. Incidence and risk factors of limb ischaemia in adult patients receiving veno-arterial extracorporeal membrane oxygenation: a systematic review and meta-analysis. *Nurs Crit Care*. 2026;31:e70365. https://doi.org/10.1111/nicc.70365

5. Rutherford RB, Baker JD, Ernst C, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. *J Vasc Surg*. 1997;26:517-538. https://doi.org/10.1016/S0741-5214(97)70045-4

6. Shishehbor MH. Acute and critical limb ischemia: when time is limb. *Cleve Clin J Med*. 2014;81:209-216. https://doi.org/10.3949/ccjm.81gr.13003

7. Falluji N, Mukherjee D. Critical and acute limb ischemia: an overview. *Angiology*. 2014;65:137-146. https://doi.org/10.1177/0003319712470966

8. Schumann R, Rieger J, Ludwig M. Acute peripheral arterial occlusive disease. *Med Klin (Munich)*. 2007;102:457-471. https://doi.org/10.1007/S00063-007-1059-7

9. Olinic DM, Stanek A, Taru DA, et al. Acute limb ischemia: an update on diagnosis and management. *J Clin Med*. 2019;8:1215. https://doi.org/10.3390/JCM8081215

10. Howard DPJ, Banerjee A, Fairhead JF, et al. Population-based study of incidence, risk factors, outcome, and prognosis of ischemic peripheral arterial events: implications for prevention. *Circulation*. 2015;132:1805-1815. https://doi.org/10.1161/CIRCULATIONAHA.115.016424

11. Jongkind V, Earnshaw JJ, Bastos Gonçalves F, et al. Editor's choice – update of the European Society for Vascular Surgery (ESVS) 2020 clinical practice guidelines on the management of acute limb ischaemia in light of the COVID-19 pandemic, based on a scoping review of the literature. *Eur J Vasc Endovasc Surg*. 2022;63:80-89. https://doi.org/10.1016/j.ejvs.2021.08.028

12. Djavidi N, Boussouar S, Duceau B, et al. Vascular complications after venoarterial extracorporeal membrane oxygenation support: a CT study. *Crit Care Med*. 2025;53:e96-e108. https://doi.org/10.1097/CCM.0000000000006476

13. Trieu NHK, Phan XT, Tran LT, et al. Risk factors for cannula-associated arterial thrombosis following extracorporeal membrane oxygenation support: a retrospective study. *Acute Crit Care*. 2023;38:315-324. https://doi.org/10.4266/acc.2023.00500

14. Bonicolini E, Martucci G, Simons J, et al. Limb ischemia in peripheral veno-arterial extracorporeal membrane oxygenation: a narrative review of incidence, prevention, monitoring, and treatment. *Crit Care*. 2019;23:266. https://doi.org/10.1186/s13054-019-2541-3

15. Miranda M, Balarini M, Caixeta D, et al. Microcirculatory dysfunction in sepsis: pathophysiology, clinical monitoring, and potential therapies. *Am J Physiol Heart Circ Physiol*. 2016;311:24-35. https://doi.org/10.1152/ajpheart.00034.2016.-Abnormal

16. Yeh YC, Chiu CT. Association and dissociation of microcirculation and macrocirculation in critically ill patients with shock. *J Emerg Crit Care Med*. 2019;3:60-60. https://doi.org/10.21037/jeccm.2019.10.05

17. Challa ST, Hargens AR, Uzosike A, Macias BR. Muscle microvascular blood flow, oxygenation, pH, and perfusion pressure decrease in simulated acute compartment syndrome. *J Bone Joint Surg Am*. 2017;99:1453-1459. https://doi.org/10.2106/JBJS.16.01191

18. Mallat J, Rahman N, Hamed F, Hernandez G, Fischer MO. Pathophysiology, mechanisms, and managements of tissue hypoxia. *Anaesth Crit Care Pain Med*. 2022;41:101087. https://doi.org/10.1016/j.accpm.2022.101087

19. Björck M, Earnshaw JJ, Acosta S, et al. European Society for Vascular Surgery (ESVS) 2020 clinical practice guidelines on the management of acute limb ischaemia. *Eur J Vasc Endovasc Surg*. 2020;59:173-218. https://doi.org/10.1016/j.ejvs.2019.09.006

20. Simon F, Oberhuber A, Floros N, et al. Acute limb ischemia—much more than just a lack of oxygen. *Int J Mol Sci*. 2018;19:374. https://doi.org/10.3390/ijms19020374

21. Fisser C, Armbrüster C, Wiest C, et al. Arterial and venous vascular complications in patients requiring peripheral venoarterial extracorporeal membrane oxygenation. *Front Med*. 2022;9:960716.

22. Sandgren T, Sonesson B, Ahlgren AR, et al. The diameter of the common femoral artery in healthy human: influence of sex, age, and body size. *J Vasc Surg*. 1999;29:503-510. https://doi.org/10.1016/S0741-5214(99)70279-X

23. Kim O, Hong D, Choi KH, et al. Sex differences in patients with cardiogenic shock receiving venoarterial extracorporeal membrane oxygenation. *Korean Circ J*. 2025;55:541-551. https://doi.org/10.4070/kcj.2024.0330

24. Soyoye DO, Abiodun OO, Ikem RT, Kolawole BA, Akintomide AO. Diabetes and peripheral artery disease: a review. *World J Diabetes*. 2021;12:827-838. https://doi.org/10.4239/wjd.v12.i6.827

25. Stapleton PA, James ME, Goodwill AG, Frisbee JC. Obesity and vascular dysfunction. *Pathophysiology*. 2008;15:79-89. https://doi.org/10.1016/j.pathophys.2008.04.007

26. Hamam O, Garg T, Elmandouh O, et al. Baseline characteristics associated with good collateral status using hypoperfusion index as an outcome. *Tomography*. 2022;8:1885-1894. https://doi.org/10.3390/tomography8040159

27. Desormais I, Aboyans V, Bura A, et al. Anemia, an independent predictive factor for amputation and mortality in patients hospitalized for peripheral artery disease. *Eur J Vasc Endovasc Surg*. 2014;48:202-207. https://doi.org/10.1016/j.ejvs.2014.04.005

28. Grandhomme J, Kuntz S, Shwein A, et al. Radiation-induced lower-limb arteriopathy: report of 4 cases and systematic literature review. *Int Angiol*. 2021;40:222-228. https://doi.org/10.23736/S0392-9590.21.04606-X

29. van der Gaag A, Cohen SP, Stojanovic MP, et al. Vascular pain: ischemic pain in the extremities and Raynaud's syndrome. *Pain Pract*. 2025;25:e13421. https://doi.org/10.1111/papr.13421

30. Gerhard-Herman MD, Gornik HL, Barrett C, et al. 2016 AHA/ACC guideline on the management of patients with lower extremity peripheral artery disease: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*. 2017;135:e686-e725. https://doi.org/10.1161/CIR.0000000000000470

31. Divakaran S, Krawisz AK, Secemsky EA, Kant S. Sex and racial disparities in peripheral artery disease. *Arterioscler Thromb Vasc Biol*. 2023;43:2099-2114. https://doi.org/10.1161/ATVBAHA.123.319399

32. Brockaert T, Ferreira I, Laplante A, et al. Preventing acute limb ischemia during VA-ECMO—in silico analysis of physical parameters associated with lower limb perfusion. *J Clin Med*. 2023;12:6049. https://doi.org/10.3390/jcm12186049

33. Wiley JM, White CJ, Uretsky BF. Noncoronary complications of coronary intervention. *Catheter Cardiovasc Interv*. 2002;57:257-265. https://doi.org/10.1002/ccd.10307

34. Mengal MN, Ashraf T, Hassan Rizvi SN, et al. Assessment of femoral artery bifurcation level with conventional angiography. *Cureus*. 2018;10:e3479. https://doi.org/10.7759/cureus.3479

35. Minici R, Paone S, Talarico M, et al. Percutaneous treatment of vascular access-site complications: a ten years' experience in two centres. *CVIR Endovasc*. 2020;3:29. https://doi.org/10.1186/s42155-020-00120-7

36. Saugel B, Scheeren TWL, Teboul JL. Ultrasound-guided central venous catheter placement: a structured review and recommendations for clinical practice. *Crit Care*. 2017;21:225. https://doi.org/10.1186/s13054-017-1814-y

37. Livesey M, Jauregui JJ, Hamaker MC, et al. Management of vasopressor induced ischemia. *J Orthop*. 2020;22:497-502. https://doi.org/10.1016/j.jor.2020.10.012

38. De Backer D, Ricottilli F, Ospina-Tascón GA. Septic shock: a microcirculation disease. *Curr Opin Anaesthesiol*. 2021;34:85-91. https://doi.org/10.1097/ACO.0000000000000957

39. Shariq M, Premnath KPB, Saleh AT, Coker J. Complications with the use of Angio-Seal vascular closure device and their management. *J Clin Imaging Sci*. 2023;13:26. https://doi.org/10.25259/JCIS_68_2023

40. Kwok CS, Rao SV, Myint PK, et al. Major bleeding after percutaneous coronary intervention and risk of subsequent mortality: a systematic review and meta-analysis. *Open Heart*. 2014;1:e000021. https://doi.org/10.1136/openhrt-2013

41. Novak M, Penhaker M, Raska P, et al. Extremity compartment syndrome: a review with a focus on non-invasive methods of diagnosis. *Front Bioeng Biotechnol*. 2022;10:801586. https://doi.org/10.3389/fbioe.2022.801586

42. Barnig C, Lutzweiler G, Giannini M, et al. Resolution of inflammation after skeletal muscle ischemia-reperfusion injury: a focus on the lipid mediators lipoxins, resolvins, protectins and maresins. *Antioxidants*. 2022;11:1213. https://doi.org/10.3390/antiox11061213

43. Paraggio L, Bianchini F, Aurigemma C, et al. Femoral large bore sheath management: how to prevent vascular complications from vessel puncture to sheath removal. *Circ Cardiovasc Interv*. 2024;17:e014156. https://doi.org/10.1161/CIRCINTERVENTIONS.124.014156

44. Osofsky RB, Owen B, Gupta J Das, et al. Cannula-associated limb ischemia severity score predicts need for distal perfusion catheter placement in venoarterial extracorporeal membrane oxygenation patients. *J Vasc Surg*. 2020;72:e129-e130. https://doi.org/10.1016/j.jvs.2020.04.232

45. Hemingway J, Emanuels D, Aarabi S, et al. Safety of transfer, type of procedure, and factors predictive of limb salvage in a modern series of acute limb ischemia. *J Vasc Surg*. 2019;69:1174-1179. https://doi.org/10.1016/j.jvs.2018.08.174

46. Mills JL, Conte MS, Armstrong DG, et al. The society for vascular surgery lower extremity threatened limb classification system: risk stratification based on wound, ischemia, and foot infection (WIfI). *J Vasc Surg*. 2014;59:220-234. https://doi.org/10.1016/j.jvs.2013.08.003

47. Eltelbany M, Fabbri M, Batchelor WB, et al. Best practices for vascular arterial access and closure: a contemporary guide for the cardiac catheterization laboratory. *Front Cardiovasc Med*. 2024;11:1349480. https://doi.org/10.3389/fcvm.2024.1349480

48. Rosseel L, Montarello NJ, Nuyens P, et al. A systematic algorithm for large-bore arterial access closure after TAVI: the TAVI-MultiCLOSE study. *EuroIntervention*. 2024;20:E354-E362. https://doi.org/10.4244/EIJ-D-23-00725

49. American Society of Anesthesiologists Task Force. Practice guidelines for central venous access 2020: an updated report by the American Society of Anesthesiologists Task Force on Central Venous Access. *Anesthesiology*. 2020;132:8-43. https://doi.org/10.1097/ALN.0000000000002864

50. Vegas A, Wells B, Braum P, et al. Guidelines for performing ultrasound-guided vascular cannulation: recommendations of the American Society of Echocardiography. *J Am Soc Echocardiogr*. 2025;38:57-91. https://doi.org/10.1016/j.echo.2024.12.004

51. 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;3:751-758. https://doi.org/10.1016/j.jcin.2010.04.015

52. Jolly SS, Alrashidi S, D'Entremont MA, et al. Routine ultrasonography guidance for femoral vascular access for cardiac procedures: the UNIVERSAL randomized clinical trial. *JAMA Cardiol*. 2022;7:1110-1118. https://doi.org/10.1001/jamacardio.2022.3399

53. Bernardi FL de M, Bernardi GL de M, Barbiero JR, et al. A six-step approach for optimizing ultrasound-guided femoral artery access. *Catheter Cardiovasc Interv*. 2025;106:1023-1031. https://doi.org/10.1002/ccd.31646

54. de Athayde Soares R, Matielo MF, Brochado Neto FC, et al. The importance of the superficial and profunda femoris arteries in limb salvage following endovascular treatment of chronic aortoiliac occlusive disease. *J Vasc Surg*. 2018;68:1422-1429. https://doi.org/10.1016/j.jvs.2018.02.052

55. Watts MM. Pharmacology of peripheral arterial disease in the angio suite: what every interventionalist should know. *Semin Intervent Radiol*. 2018;35:393-398. https://doi.org/10.1055/s-0038-1676329

56. Arroyo D, Bendjelid K, Robert-Ebadi H, et al. Suspected arterial vasospasm in femoro-femoral venoarterial extracorporeal life support. *ASAIO J*. 2017;63:e35-e38. https://doi.org/10.1097/MAT.0000000000000423

57. Camboni D, Philip A, Schmid C, Loforte A. Double, triple and quadruple cannulation for veno-arterial extracorporeal membrane oxygenation support: Is there a limit? *Ann Cardiothorac Surg*. 2019;8:151-159. https://doi.org/10.21037/acs.2019.01.03

58. Hart JP, Davies MG. Vascular complications in extracorporeal membrane oxygenation—a narrative review. *J Clin Med*. 2024;13:5170. https://doi.org/10.3390/jcm13175170

59. Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis*. 2020;75(suppl 2):S1-S164.

60. Lorusso R, Shekar K, MacLaren G, et al. ELSO interim guidelines for venoarterial extracorporeal membrane oxygenation in adult cardiac patients. *ASAIO J*. 2021;67:827-844. https://doi.org/10.1097/MAT.0000000000001510

61. Simons J, Mees B, MacLaren G, et al. Evolution of distal limb perfusion management in adult peripheral venoarterial extracorporeal membrane oxygenation with femoral artery cannulation. *Perfusion*. 2024;39(suppl):23S-38S. https://doi.org/10.1177/02676591241236650

62. Patton-Rivera K, Beck J, Fung K, et al. Using near-infrared reflectance spectroscopy (NIRS) to assess distal-limb perfusion on venoarterial (V-A) extracorporeal membrane oxygenation (ECMO) patients with femoral cannulation. *Perfusion*. 2018;33:618-623. https://doi.org/10.1177/0267659118777670

63. Creager MA, Kaufman JA, Conte MS. Acute limb ischemia. *N Engl J Med*. 2012;366:2198-2206.

64. Lichaa H. The "lend a hand" external bypass technique: external radial to femoral bypass for antegrade perfusion of an ischemic limb with occlusive large bore sheath - a novel and favorable approach. *Catheter Cardiovasc Interv*. 2020;96:E614-E620. https://doi.org/10.1002/ccd.29187

65. Elmously A, Bobka T, Khin S, et al. Distal perfusion cannulation and limb complications in venoarterial extracorporeal membrane oxygenation. *J Extra Corpor Technol*. 2018;50:155-160.

66. Zhang Q, Guo K, Liu Y, et al. Perclose ProGlide closure devices vs. surgical removal for veno-arterial extracorporeal membrane oxygenation decannulation: a meta-analysis. *Front Cardiovasc Med*. 2025;12:1482305. https://doi.org/10.3389/fcvm.2025.1482305