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Article

Effect of Hyperperfusion on Radial Artery Catheterization and Arterial Blood Gas Analysis in Patients With Acute Heart Failure

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Abstract

Background: This study aimed to determine the impact of radial artery (RA) hyperperfusion on the first-attempt success rate of arterial catheterization and the accuracy of arterial blood gas analysis in patients with acute heart failure (AHF). **Methods:** From March 2024 to January 2026, 356 patients with AHF admitted to the Emergency Department of our hospital were enrolled and randomly assigned to either a non-hyperperfusion group or a hyperperfusion group (178 patients per group). Randomization was performed using a random number table. The non-hyperperfusion group received conventional blind radial artery catheterization, whereas the hyperperfusion group underwent catheterization under a hyperperfusion intervention. In the hyperperfusion group, blood gas analysis samples obtained via catheter were collected once in each of the conventional and hyperperfusion conditions. The first-time success rate of RA catheterization, catheterization time, pain score, and heart rate fluctuation were compared between the two groups. In addition, we explored the impact of hyperperfusion blood collection on the precision of blood gas analysis outcomes. **Results:** The first-attempt success rate of RA catheter insertion, catheterization time, pain score, and heart rate changes in the hyperperfusion group were better than those observed in the non-hyperperfusion group, with the differences being statistically significant ($p < 0.05$). There was no significant difference in lactic acid, pH, $PaCO_2$, PaO_2, Na^+, K^+, and SaO_2 in the blood gas analysis under the hyperperfusion state compared with that in the conventional state ($p > 0.05$). **Conclusions:** The hyperperfusion method improved the first-attempt success rate of RA catheterization in patients with AHF, shortened catheterization time, reduced patient pain, and had no significant effect on the accuracy of RA blood gas analysis. **Clinical Trial Registration:** ChiCTR2500113153, https://www.chictr.org.cn/showproj.html?proj=297512.

Keywords: hyperperfusion; acute heart failure; radial artery; catheterization; blood gas analysis; accuracy

1. Introduction

Acute heart failure (AHF) is a common critical clinical illness. A sharp decline in cardiac output results in a rapid rise in pulmonary venous pressure, with the imbalance of ventilation and blood flow causing hypoxia, dyspnea, and even respiratory failure. Arterial blood gas (ABG) analysis is the core method for evaluating respiratory function, oxygenation and acid-base balance of patients [1]. In emergency wards and intensive care units, close monitoring of ABG results is usually crucial for the dynamic management and treatment of patients with AHF. However, repeated arterial punctures may lead to complications such as arterial spasm, hematoma at the puncture site, pain, and puncture difficulties [2]. Such repeated attempts can hinder arterial blood sampling and consequently delay clinical treatment. Indwelling arterial cannulas can effectively reduce these complications caused by repeated arterial puncture. Once successful catheterization is achieved, it is convenient for ABG analyses and blood tests. The radial artery (RA) is superficial and can be perfused through the collateral ulnar artery, which is an easy vessel to locate for carrying out the punctures, and is therefore the preferred site for peripherally inserted catheters [3]. However, patients with AHF often have edema, hypotension, peripheral hypoperfusion, forced posture, and anxiety and restlessness [4,5], which require nurses to develop higher operational skills. The success rate of traditional palpation RA catheter puncture is only 42%–49.45% [6,7], and in most cases, the use of B-ultrasound guidance is necessary to increase this success rate [8]. However, ultrasound equipment is expensive and nurses in China generally lack the required operational qualifications. Our study aimed to develop simple and practical methods to improve the puncture success rate for RA catheterization carried out by nurses in China. A previous study [9] showed that the use of double airbag hollow cuffs selectively blocked the ulnar artery, causing improved perfusion of the RA and enhancement of the RA pulse. This resulted in an increased diameter of the vessel and a higher success rate of the first RA puncture and blood collection, in addition to reducing patient pain and improving their satisfaction. However, the operation of RA indwelling catheter puncture is more difficult than simple arterial puncture and blood collection. At present, there are no studies on hyperperfusion methods related to RA catheterization, while the impact of this method on the results of ABG specimens remains unclear. In summary, this study aimed to explore the effects of the hyperperfusion technique on the one-time success rate of RA catheterization in patients with AHF. Meanwhile, this study evaluated whether the hyperperfusion technique exerts an influence on blood gas measurement results.

2. Methods

This single-center, prospective, randomized, controlled, non-inferiority trial was conducted at Nanjing First Hospital and aimed to evaluate the clinical application of the Multi-functional Electronic Sphygmomanometer. The study protocol received initial approval from our hospital's Ethics Committee on April 10, 2023, and an Ethics Review Report was issued, authorizing the commencement of patient recruitment and study initiation. Following project completion and final archiving, the formal ethics approval certificate (No. KY20251118-02) was granted in November 2025. The trial was retrospectively registered with the Chinese Clinical Trial Registry (registration number: ChiCTR2500113153). Although the protocol had been finalized and received ethical approval before patient enrollment, formal registration was delayed due to internal administrative procedures and a misunderstanding of the registration timeline. Following registration, the study protocol was refined, and administrative compliance was confirmed. All methods were carried out in accordance with relevant guidelines and regulations, and informed consent was obtained from all participants.

2.1 Participants

The inclusion criteria were as follows: (1) older than 14 years; (2) experiencing AHF episodes; (3) meeting the criteria for pre-screening triage level I–II [10]; (4) first collection of a RA blood specimen; (5) RA peak systolic velocity <35 cm/s; (6) RA puncture using a 22 G Y-shaped indwelling needle; and (7) being conscious and co-operative.

The exclusion criteria were as follows: (1) RA defect; (2) forearm trauma; (3) arteriovenous fistula; and (4) coagulation abnormalities.

Withdrawal criteria: Incidence of vasovagal reflexes; patient death.

2.2 Sample Size Calculation

Taking the one-time success rate of RA catheter insertion as the main observation index, with a bilateral $\alpha = 0.05$ and $\beta = 0.1$ as the test level, the one-time success rate of RA catheter insertion in the non-hyperperfusion and hyperperfusion groups in the pre-experiment was 66.7% and 83.3%, respectively. Using PASS 15 software (NCSS, LLC, Kaysville, UT, USA) and assuming a 20% dropout rate, the total sample size was calculated to be 356 cases.

2.3 Randomization

A total of 356 patients with AHF admitted to the Emergency Department of our hospital from March 2024 to January 2026 were enrolled. Eligible patients were randomly assigned in a 1:1 ratio to either the non-hyperperfusion group or the hyperperfusion group using a computer-generated randomization sequence with a fixed block size. The sequence was generated by an independent researcher who was not involved in patient recruitment, intervention, or outcome assessment. Allocation concealment was implemented using sequentially numbered, opaque, sealed envelopes (SNOSE) prepared by an independent research coordinator not affiliated with the clinical team. The allocated group assignment was revealed only after patient eligibility was fully confirmed and written informed consent was obtained.

2.4 Blind Puncture Method for RA Catheter Placement in the Non-Hyperperfusion Group

The patient was placed in the supine position with upper limb abduction, their palm up and relaxed, and a gauze roll placed under their wrist to cause approximately 30° of dorsiflexion. The operator disinfected the skin at the puncture site with Anerdian and then placed a disposable sterile towel at the point with the strongest pulse of the RA chosen as the puncture site (1–2 cm above the horizontal lines of the wrist). The operator wore gloves, with their left hand placed about 1 cm proximal to the puncture point. The index and middle fingers were used to press the direction of the artery, while the right thumb and middle finger were used to hold the 22G Y-shaped indwelling needle in the blood cavity and handle, respectively. The needle was beveled upward and directly inserted into the blood vessel at an angle of 30°–45°. After inserting the needle, the puncture angle was reduced when blood returned, and the needle core was then slowly withdrawn. At the same time, the right hand held the needle wing and placed the cannula along the direction of the blood vessel until the needle core was completely withdrawn. After successful puncture, a 3M transparent dressing was used to ensure the catheter was firmly positioned [11].

2.5 Blood Gas Analysis of the Catheter in the Conventional Procedures

For the collection of the blood samples, the three-way tap was turned on, while the arterial catheter end was closed. The heparin cap at the atmospheric end was then turned on, followed by connection of the BD arterial blood sampling needle. During subsequent blood collection, the samples were sterilized by soaking alcohol cotton pieces within the blood sample for 15 s. First, 1–2 mL of the front-end blood was withdrawn using a 5 mL syringe and discarded, followed by replacement of the BD arterial blood collection needle before blood gas analysis was performed.

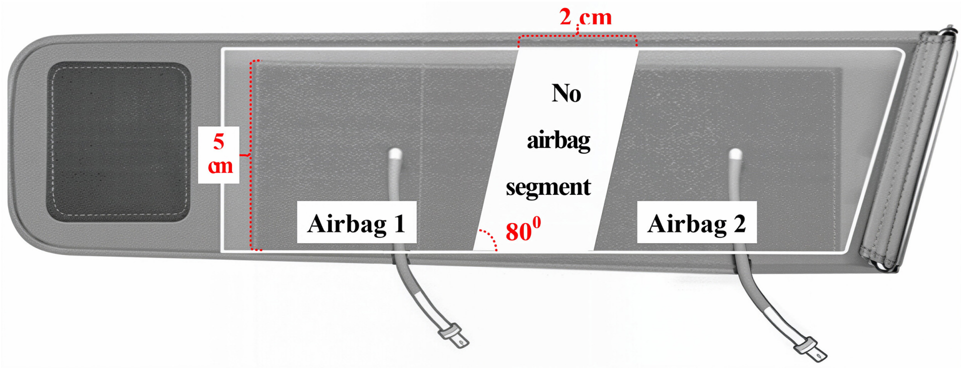

Fig. 1. Structural schematic of the custom dual-airbag hollow cuff, with two 5 × 10 cm lateral airbags separated by an 80°-inclined 5 × 2 cm non-airbag segment.

2.6 RA Catheterization in the Hyperperfusion Group

A custom multi-functional electronic sphygmomanometer (Bestman BV-520T+) combined with a double-airbag hollow cuff was used to perform the high-perfusion method. This device allows for precise, automated pressure regulation to achieve selective arterial hyperperfusion. Before RA puncture and catheterization: ① A nurse used the Bestman BV-520T+ blood flow detector to measure the blood flow signals of the RA in the forearm and to locate and mark the course of the artery; ② A 5 cm × 2 cm 80° angled no airbag segment in the middle of the custom blood pressure monitor's double-airbag hollow cuff (two 5 cm × 10 cm small airbags separated by a central 5 cm × 2 cm no airbag segment) (Fig. 1) was positioned directly above the marked RA near the elbow, and then wrapped around the forearm in a circular manner (tightness allowing insertion of one finger); ③ The preset inflation pressure of the double-airbag cuff of the personal digital assistant (PDA) was set to the patient's brachial artery systolic pressure + 30 mmHg, with the pressure applied for 5 min; ④ The start button was pressed to automatically inflate the cuff and apply pressure. This caused all the forward blood in the brachial artery to flow towards the RA, making it thicker with stronger pulsations. Puncture of the RA was performed 30 s after the application of pressure. During this period, either the shutdown button was pressed, or after 5 min the application of pressure was automatically shut down. The catheterization method of the RA was similar in the hyperperfusion and non-hyperperfusion groups [9].

2.7 Blood Gas Analysis of the Catheter in the Conventional Group

The blood gas analysis sampling method was the same as that of the non-hyperperfusion group.

2.8 Blood Gas Analysis With the Hyperperfusion Technique

After successful RA catheterization, 30 s of hyperperfusion pressure was applied to the forearm using the custom blood pressure with double-airbag hollow cuff before blood gas analysis sampling. The hyperperfusion pressure and blood gas sampling methods were the same as described previously.

2.9 Endpoints and Definitions

2.9.1 Endpoints

The primary outcome was the one-time success rate of RA catheterization. Secondary outcomes included pain score, puncture time, heart rate variation, and ABG findings.

2.9.2 Definitions

One-time success rate of RA catheterization: The rate of successful puncture during the first RA catheterization procedure.

Catheterization time: The time required from the start of skin disinfection at the puncture site to successful puncture of the RA catheter.

Pain score: The highest score of the patient during the catheterization puncture of the RA, evaluated using a numerical rating scale [12].

Heart rate variation: The difference between the highest and lowest values of heart rate after the RA catheterization puncture.

ABG findings: Lactic acid, pH, partial pressure of carbon dioxide, partial pressure of oxygen, sodium ion, potassium ion, oxygen saturation.

2.9.3 Quality Control

Given the nature of the intervention, the operators could not be blinded to the group assignment. However, the outcome assessors and data analysts were blinded to the group allocation. To minimize performance bias, a three-tier management system was established: one project leader oversaw research design and standardized operating procedures (SOPs), six deputy team leaders (senior specialized nurses at the provincial level) were assigned to be solely responsible for quality control of the research, supervision

Table 1. Comparison of general information between the two groups.

Variables	Non-hyperperfusion group (n = 178)	Hyperperfusion group (n = 178)	Statistic	p
Male, n (%)	113 (63.5)	122 (68.5)	$\chi^2 = 1.014$	0.314
Age (years)	61.79 ± 7.95	62.13 ± 8.23	$t = -0.396$	0.692
BMI (kg/m^2)	23.42 ± 2.76	23.61 ± 2.82	$t = -0.642$	0.521
Right radial artery, n (%)	172 (96.6)	169 (94.9)	$\chi^2 = 0.626$	0.429
Hypertension, n (%)	128 (71.9)	115 (64.6)	$\chi^2 = 2.191$	0.139
Diabetes, n (%)	45 (25.3)	59 (33.1)	$\chi^2 = 2.662$	0.103
Atrial fibrillation, n (%)	19 (10.7)	28 (15.7)	$\chi^2 = 1.986$	0.159

t, t-test; χ^2, Chi-square test.

Table 2. Comparison success rate, puncture time, pain score, heart rate fluctuation of RA catheterization between the two groups.

Variables	Non-hyperperfusion group (n = 178)	Hyperperfusion group (n = 178)	Statistic	p
The success rate of one-time puncture, n (%)	109 (61.2)	145 (81.5)	$\chi^2 = 17.808$	<0.001
Puncture time (s)	59.68 ± 9.28	36.89 ± 8.94	$t = 23.596$	<0.001
Pain score	4.00 (4.00, 5.00)	3.00 (2.00, 4.00)	$Z = -7.060$	<0.001
Heart rate fluctuation (beats/min)	6.00 (5.00, 7.00)	4.00 (3.00, 5.00)	$Z = -12.657$	<0.001

t, t-test; χ^2, Chi-square test; RA, radial artery.

Table 3. Comparison of arterial blood gas analysis.

Variables	hyperperfusion status (n = 178)	Conventional status (n = 178)	Statistic	p
Lactic acid (mmol/L)	1.76 ± 0.17	1.79 ± 0.18	$t = -1.569$	0.119
pH	7.41 ± 0.14	7.38 ± 0.13	$t = 1.670$	0.097
$PaCO_2$ (mmHg)	36.86 ± 3.43	36.97 ± 3.49	$t = -0.292$	0.771
PaO_2 (mmHg)	85.35 ± 10.47	84.15 ± 10.26	$t = 1.100$	0.273
K^+ (mmol/L)	3.94 ± 0.33	3.89 ± 0.29	$t = 1.455$	0.147
Na^+ (mmol/L)	139.82 ± 8.46	140.02 ± 8.51	$t = -0.237$	0.813
SaO_2 (%)	88.61 ± 4.19	87.93 ± 3.85	$t = 1.602$	0.111

t, Paired sample t-tests.

of randomization and enrollment of the patients, while 10 team members (senior charge nurses) carried out enrollment of the patients, implementation of the clinical interventions, and collection of the data. senior specialized nurses supervised quality control and randomization, and ten senior charge nurses performed patient enrollment, interventions, and data collection. All personnel completed centralized, standardized training and passed uniform skill assessments before study initiation. All procedures followed SOPs, with evaluations and data collection rigorously double-checked to ensure consistency and reliability.

2.10 Statistical Analysis

The statistical analyses were conducted using SPSS 25.0 (IBM Corp, Armonk, NY, USA) software. Categorical data were expressed as frequency and percentage and analyzed using the χ^2 test. Normally distributed measurement data were expressed as $\bar{x} \pm s$, with comparisons between groups performed using two independent sample t-tests, while non-normally distributed measurement data were expressed as median and quartiles, and comparisons between groups conducted using the Mann-Whitney U test. Paired sample t-tests were used for the results of the blood gas analyses of the two different states of the catheters within the hyperperfusion group. In all the analyses, differences were considered statistically significant when $p < 0.05$. Given the standardized training and certification of operators, a simple fixed-effects model was used.

3. Results

3.1 Baseline Characteristics

A total of 356 patients were enrolled in this study from March 2024 to January 2026. There were no significant differences between the two groups in terms of age (61.79 ± 7.95 yr vs. 62.13 ± 8.23 yr, p = 0.692), male gender (63.5% vs. 68.5%, p = 0.314), BMI (23.42 ± 2.76 kg/m^2 vs. 23.61 ± 2.82 kg/m^2, p = 0.521), and right radial artery (96.6% vs. 94.9%, p = 0.429). There were also no significant differences between the two groups in terms of the prevalence of hypertension (71.9% vs. 64.6%, p = 0.139), diabetes (25.3% vs. 33.1%, p = 0.103), and atrial fibrillation (10.7% vs. 15.7%, p = 0.159) (Table 1).

3.2 Comparison of Indicators Related to RA Catheterization

As shown in Table 2, the non-hyperperfusion group showed a lower success rate of one-time puncture (61.2% vs. 81.5%, $p < 0.001$) and longer puncture time (59.68 ± 9.28 s vs. 36.89 ± 8.94 s, $p < 0.001$). In addition, there were significant differences between the two groups for pain score (4.00 [4.00, 5.00] vs. 3.00 [2.00, 4.00], $p < 0.001$), and heart rate fluctuation (6.00 [5.00, 7.00] vs. 4.00 [3.00, 5.00], $p < 0.001$).

3.3 Comparison of ABG Findings

As shown in Table 3, the results of ABG analysis revealed no significant differences between hyperperfusion status and conventional status. Specifically, the results were comparable in terms of lactic acid (1.76 ± 0.17 mmol/L vs. 1.79 ± 0.18 mmol/L, p = 0.119), pH (7.41 ± 0.14 vs. 7.38 ± 0.13, p = 0.097), $PaCO_2$ (36.86 ± 3.43 mmHg vs. 36.97 ± 3.49 mmHg, p = 0.771), PaO_2 (85.35 ± 10.47 mmHg vs. 84.15 ± 10.26 mmHg, p = 0.273), K^+ (3.94 ± 0.33 mmol/L vs. 3.89 ± 0.29 mmol/L, p = 0.147), Na^+ (139.82 ± 8.46 mmol/L vs. 140.02 ± 8.51 mmol/L, p = 0.813), and SaO_2 (%) (88.61 ± 4.19 vs. 87.93 ± 3.85, p = 0.111).

4. Discussion

By implementing hyperperfusion through the use of a custom double-airbag hollow cuff, the success rate of RA catheterization in patients with AHF can be improved significantly, the catheterization time shortened, and the pain score and heart rate fluctuation reduced. Using the same catheter in a patient and with standardized blood collection procedures, the collection of ABG specimens in a hyperperfusion state showed no statistically significant difference in core parameters compared to those achieved using the conventional state. These findings indicated a high-level of self-control regarding the safety of this technique.

4.1 Hyperperfusion Increased the Success Rate of RA Catheterization Puncture in Patients With AHF, Shortened the Catheterization Time, and Reduced Pain and Heart Rate Fluctuations

In China, nurses often direct operators during the collection of ABG samples. The method of ABG collection is closely related to the success rate of blood collection, the accuracy of the samples, the occurrence of complications, and the patient's experience. Patients with AHF often have peripheral hypoperfusion, tissue edema, and abnormal vascular tension, which lead to weak pulsation of the RA, thin vessel diameter, and difficulty in positioning, thereby reducing the one-time success rate of traditional blind puncture catheterization of the artery [13,14]. Kim et al. [15] reported that compression of the ulnar artery increased the diameter of the RA by approximately 18%, although their study focused only on a single puncture blood collection and did not evaluate the operational efficiency and specimen stability in the catheter retention scenario.

Our findings demonstrated superior performance of RA catheterization-related indicators in the hyperperfusion group, which is consistent with previous studies by Kim et al. [15] and Bahrami et al. [16]. In our hyperperfusion Strategy, ultrasound localization guarantees precise anatomical positioning. Meanwhile, arteries other than the RA trunk are selectively occluded to direct blood perfusion toward the RA.

The 30-s hyperperfusion window period also coincided precisely with the physiological plateau period of the degree of maximum filling and pulsation intensity of the blood vessels [17]. This mechanism not only significantly increased the cross-sectional area of the RA, but more importantly, simultaneously enhanced its pulsation amplitude and blood flow velocity [18]. Collectively, this technique allows precise anatomical localization and concurrent optimization of vascular diameter, pulsation perception, and puncture resistance. Such synergistic effects contribute to an elevated first-attempt success rate and reduced procedural duration of RA catheterization.

The hyperperfusion technique alleviates pain during radial artery catheterization. This study provides both subjective and objective evidence. We not only recorded patient-reported pain scores, but also monitored heart rate variations during puncture in patients with AHF, establishing quantifiable physiological indicators for pain assessment. Elevated heart rate reflects a physiological stress response. Patients in the hyperperfusion group showed less heart rate fluctuations, objectively confirming that this technique can effectively reduce puncture-related stress and pain. Pain relief stems primarily from the higher success rate of one-time puncture and adequate vasodilation. Repeated attempts trigger sustained contraction of radial artery smooth muscle, leading to vasospasm and mechanical vascular injury. Additionally, adequate vasodilation reduces local pressure and irritation exerted by the needle tip on vessel walls.

Previous studies [19,20] have adopted cold compress and local anesthesia to alleviate puncture pain. However, subcutaneous anesthetic injection may interfere with blood sampling and test results. It has also been reported to cause hypotension and diminished radial artery pulse, further increasing puncture difficulty [21]. The time from local anesthesia to RAP is 0–5 minutes for local anesthetic infiltration, cryotherapy, and lidocaine spray, whereas that for topical anesthesia other than lidocaine spray is longer (20–240 minutes) [19]. By contrast, our technique saves operational duration.

4.2 Under Hyperperfusion Status, Blood Sampling Through the RA Catheter Had No Significant Impact on the Accuracy of Blood Gas Analysis Results

The influence of performing blood sampling through the RA catheter under hyperperfusion status on errors in blood gas analysis merits clinical investigation. Previous concerns about the potential impact of physical intervention on the results of blood gas analyses mainly stemmed from two points. The first was whether hyperperfusion caused "excessive oxygenation" of local tissues, leading to a false increase in PaO_2 or a false decrease in lactic acid, while the second was whether the improvement in operational convenience came at the expense of specimen quality. The results showed that our hyperperfusion strategy did not cause any clinical or statistically significant bias in the accuracy of all the core blood gas parameters. Regarding the reliability of the blood gas analysis results, this rigorous self-controlled design yields the highest level of evidence reported so far.

Abnormal blood gas parameters, including elevated lactic acid, reduced pH, and decreased arterial partial pressure of oxygen are prevalent in patients with AHF, which stem from mitochondrial hypoxia and anaerobic glycolysis caused by systemic hypoperfusion [22]. Transient local hemodynamic changes in the forearm cannot reverse the pathological state of such patients. Furthermore, brief hyperperfusion for 30-s does not change either the efficiency of pulmonary gas exchange (determinate of PaO_2/SaO_2), reverse tissue hypoxic metabolism (determined by lactic acid), or interfere with the bicarbonate buffering system (determined by $pH/PaCO_2$). We also observed that there were no differences in serum potassium and sodium concentrations between the conventional status and hyperperfusion status, which was related to their main regulation by systemic water-salt balance, the renin-angiotensin-aldosterone system, and the activity of Na^+/K^+-ATPase in cell membranes [23]. The brief local hyperperfusion in the forearm also did not change renal hemodynamics or disrupt the steady state of ion transmembrane transport across the cell membrane, as it was difficult to disturb the circulating concentrations within the short window of the blood collection. Moreover, circulation in the RA is an arterial terminal branch, with its electrolyte composition closely reflecting the central circulation state, rather than local microenvironment fluctuations [24]. It has been confirmed that 75% of the errors found originate from the analytical pre-step [25]. This technique reduced the risk of analytical errors such as hemolysis and bubble contamination by avoiding repeated punctures and reducing violent suction, which is prone to hemolysis. This further ensured the stability of the test results.

5. Limitations

Several limitations warrant consideration. First, as a single-center trial conducted in a tertiary teaching hospital, our findings may be subject to selection bias. The high success rate observed might be attributable to the exceptional expertise of our nursing team, which may not be generalizable to hospitals with less experienced staff or limited resources. Second, despite rigorous standardization, the hyperperfusion technique is inherently more complex than conventional palpation methods. It requires precise coordination of cuff pressure and timing. We acknowledge that there is likely a significant learning curve associated with this technique. While our operators were highly trained, the dependency on operator skill remains a potential confounding factor that could affect the reproducibility of these results in real-world settings with varying levels of practitioner experience.

6. Conclusions

In patients with AHF, high-pressure radial artery compression using a custom device fitted with a double-airbag hollow cuff optimizes radial artery catheterization. This technique raises the procedural success rate, shortens operating time, eases puncture-induced pain and stabilizes heart rate, while exerting no adverse effects on the reliability of radial artery blood gas measurements. This technique is simple, safe, and highly reproducible, and can be safely popularized in coronary care unit (CCU), intensive care unit (ICU), and emergency departments requiring frequent dynamic blood gas monitoring.

Availability of Data and Materials

The data that support the findings of this study are available on request from the corresponding author.

Author Contributions

CCF and MZ designed and refined the research study. CCF, MZ, HW, YQZ and WXF performed the clinical research and collected clinical data. CCF and MZ analyzed the data and drafted the manuscript. JMQ supervised the whole research, provided critical guidance on the study design, and revised the manuscript for important intellectual content. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study protocol received initial approval from our hospital's Ethics Committee on April 10, 2023, and an Ethics Review Report was issued. Following project completion and final archiving, the formal ethics approval certificate (No. KY20251118-02) was granted in November 2025. The trial was retrospectively registered with the Chinese Clinical Trial Registry (registration number: ChiCTR2500113153). All methods were carried out in accordance with relevant ICMJE guidelines and Helsinki

Declaration. All procedures were performed after obtaining consent from both the patients themselves and their legal guardians, and written informed consent was signed by the legal guardians.

Acknowledgment

Not applicable.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Castro D, Patil S, Zubair M, Keenaghan M. Arterial Blood Gas. StatPearls Publishing: Treasure Island (FL). 2026.

[2] Roy S, Kabach M, Patel DB, Guzman LA, Jovin IS. Radial Artery Access Complications: Prevention, Diagnosis and Management. Cardiovascular Revascularization Medicine: Including Molecular Interventions. 2022; 40: 163–171. https://doi.org/10.1016/j.carrev.2021.12.007

[3] Singh R. Variations in the origin, course and branching pattern of the radial artery along with clinical correlations: narrative review. Jornal Vascular Brasileiro. 2025; 24: e20240015. https://doi.org/10.1590/1677-5449.202400152

[4] Kim HJ, Jo SH. Effect of low blood pressure on prognosis of acute heart failure. Scientific Reports. 2024; 14: 15605. https://doi.org/10.1038/s41598-024-66219-2

[5] Mazimba S, Mwansa H, Breathett K, Strickling JE, Shah K, McNamara C, et al. Systemic arterial pulsatility index (SAPi) predicts adverse outcomes in advanced heart failure patients. Heart and Vessels. 2022; 37: 1719–1727. https://doi.org/10.1007/s00380-022-02070-7

[6] Toledano BRF, Garganera KB, Prado JPA, Sabas ML. Routine preprocedural ultrasound in palpation versus ultrasound guided radial access for cardiac catheterization. Catheterization and Cardiovascular Interventions. 2024; 103: 722–730. https://doi.org/10.1002/ccd.31005

[7] Seyhan AU, Ak R. Ultrasound guidance versus conventional technique for radial artery puncture in septic shock patients: A pilot study. The Journal of Vascular Access. 2023; 24: 133–139. https://doi.org/10.1177/11297298211023299

[8] Zhao W, Peng H, Li H, Yi Y, Ma Y, He Y, et al. Effects of ultrasound-guided techniques for radial arterial catheterization: A meta-analysis of randomized controlled trials. The American Journal of Emergency Medicine. 2021; 46: 1–9. https://doi.org/10.1016/j.ajem.2020.04.064

[9] Zhang M, Shi YH, Qiao JM, Zhou YQ, Wang H, Fang WX. Effect of Hyperperfusion on Successful Collection of Arterial Blood Gas Specimens in Patients With Acute Heart Failure. Cardiology Research. 2025; 16: 338–345. https://doi.org/10.14740/cr2076

[10] Rao SV, O'Donoghue ML, Ruel M, Rab T, Tamis-Holland JE, Alexander JH, et al. 2025 ACC/AHA/ACEP/NAEMSP/SCAI Guideline for the Management of Patients With Acute Coronary Syndromes: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation. 2025; 151: e771–e862. https://doi.org/10.1161/CIR.0000000000001309

[11] Imbriaco G, Spencer TR, Bardin-Spencer A. 10 best practice tips with radial arterial catheterization. The Journal of Vascular Access. 2024; 25: 363–368. https://doi.org/10.1177/11297298221101243

[12] Downie WW, Leatham PA, Rhind VM, Wright V, Branco JA, Anderson JA. Studies with pain rating scales. Annals of the Rheumatic Diseases. 1978; 37: 378–381. https://doi.org/10.1136/ard.37.4.378

[13] McDonagh TA, Metra M, Adamo M, Gardner RS, Baumbach A, Böhm M, et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. European Heart Journal. 2021; 42: 3599–3726. https://doi.org/10.1093/eurheartj/ehab368

[14] Zus AS, Crișan S, Luca S, Nișulescu D, Valcovici M, Pătru O, et al. Topical Nitroglycerin for Radial Access Optimization: Supporting Vascular Access in Patients at Risk for Acute Heart Failure. Medicina. 2025; 61: 1016. https://doi.org/10.3390/medicina61061016

[15] Kim CL, Hong SW, Kim SH. Effects of Compression of the Ulnar Artery on the Radial Artery Catheterization. Journal of Clinical Medicine. 2022; 11: 5476. https://doi.org/10.3390/jcm11185476

[16] Bahrami F, Mirshafiee S, Mansouri P, Eftekhari M, Vahidi M, Baharvand F, et al. Comparison of Brachial Compression Versus Ulnar Compression on Radial Artery Diameter: A Randomized Controlled Trial. International Journal of Vascular Medicine. 2024; 2024: 9965794. https://doi.org/10.1155/2024/9965794

[17] Qi W, Ma H, Wu X, Wei K, Li Y. The optimal puncture time point of prolonged occlusion flow-mediated dilatation in radial artery catheterization: a prospective observational study. Scientific Reports. 2023; 13: 21752. https://doi.org/10.1038/s41598-023-49122-0

[18] Doubell J, Kyriakakis C, Weich H, Herbst P, Pecoraro A, Moses J, et al. Radial artery dilatation to improve access and lower complications during coronary angiography: the RADIAL trial. EuroIntervention. 2021; 16: 1349–1355. https://doi.org/10.4244/EIJ-D-19-00207

[19] Yasuo S, Hayashi M, Suda C, Kataoka Y, Taito S, Imai E, et al. Efficacy of Local Anesthesia for Radial Artery Puncture Pain: A Systematic Review and Network Meta-Analysis. Cureus. 2024; 16: e64682. https://doi.org/10.7759/cureus.64682

[20] Gonella S, Clari M, Conti A, Simionato L, Tassone C, Berchialla P, et al. Interventions to reduce arterial puncture-related pain: A systematic review and meta-analysis. International Journal of Nursing Studies. 2022; 126: 104131. https://doi.org/10.1016/j.ijnurstu.2021.104131

[21] Gitman M, Barrington MJ. Local Anesthetic Systemic Toxicity: A Review of Recent Case Reports and Registries. Regional Anesthesia and Pain Medicine. 2018; 43: 124–130. https://doi.org/10.1097/aap.0000000000000721

[22] Gajewski P, Wilk MM, Aleksandrowicz K, Ponikowska B, Zymliński R. Lactate in Heart Failure. International Journal of Molecular Sciences. 2025; 26: 6810. https://doi.org/10.3390/ijms26146810

[23] Miller WL. Fluid Volume Homeostasis in Heart Failure: A Tale of 2 Circulations. Journal of the American Heart Association. 2022; 11: e026668. https://doi.org/10.1161/JAHA.122.026668

[24] Treger R, Pirouz S, Kamangar N, Corry D. Agreement between central venous and arterial blood gas measurements in the intensive care unit. Clinical Journal of the American Society of Nephrology. 2010; 5: 390–394. https://doi.org/10.2215/CJN.00330109

[25] Kadwa AR, Grace JF, Zeiler GE. Sources of error in acid-base analysis from a blood gas analyser result: a narrative review. Journal of the South African Veterinary Association. 2022; 93: 89–98. https://doi.org/10.36303/JSAVA.163