

Impact of Local Forearm Heating on Pain Intensity and Hemorrhage in Patients Undergoing Radial Artery Cardiac Catheterization: A Pilot Study

ABSTRACT

Background: Radial artery cardiac catheterization is a common diagnostic and interventional procedure for cardiovascular conditions. Pain and hemorrhage at the access site can cause patient discomfort and complications. This pilot study investigates the potential of local forearm heating to reduce pain and hemorrhage in patients undergoing radial artery cardiac catheterization.

Methods: We enrolled 100 patients scheduled for radial artery cardiac catheterization and randomly assigned them to the heating or control group. The heating group received local forearm heating before sheath removal, while the control group did not. Pain intensity was assessed with a visual analog scale, and hemorrhage was measured by assessing ecchymosis or hematoma size at the catheterization site. Hemodynamic parameters were also monitored. Statistical analysis compared outcomes between the groups.

Results: Patients who received local forearm heating had significantly lower pain intensity (4.15 ± 2.73) compared to the control group (5.84 ± 3.34) ($P = .009$). Hemodynamic parameters and the extent of hemorrhage at the catheterization site did not significantly differ between the heating and control groups ($P > .05$). No adverse effects related to forearm heating were reported.

Conclusion: Local forearm heating is a promising intervention to reduce pain intensity without increasing hemorrhage or affecting hemodynamic parameters during radial artery cardiac catheterization. This simple, noninvasive approach has the potential to enhance patient comfort and safety post procedure.

Keywords: Cardiac catheterization, heating, pain, hemorrhage

INTRODUCTION

Percutaneous coronary intervention (PCI) stands as a nonsurgical yet invasive modality, widely recognized as the gold standard for both therapeutic and diagnostic purposes in the context of coronary artery disease (CAD), a leading global cause of mortality.^{1,2} Percutaneous coronary intervention can be performed through 2 primary access routes: the trans-radial and trans-femoral arteries. However, trans-radial coronary intervention (TCI) is preferable due to its superficial vascular position and the alternative blood supply from the ulnar artery.^{3,4} Conversely, TCI is associated with complications such as radial artery spasm, hematoma, and bleeding, presenting inherent challenges.^{5,6} Therefore, the treatment and especially prevention of such complications should be included in the agenda. According to the pathophysiology of spasm (small vessel diameter and the presence of α -adrenergic receptors in the muscular layer of the artery, which causes increased sensitivity to pain, thereby intensifying the spasm), it is possible to prevent complications with vascular dilation mediators and alleviate patients' pain during PCI.^{5,7} Many studies investigated radial artery dilation with systemic or local mediators. However, few of them discussed the importance of pain relief, the acute and chronic complications, and the management methods.^{4,7}

ORIGINAL INVESTIGATION

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In addition to causing patients' discomfort, inadequate management of post-procedural pain at the access site can result in chronic pain, which can impair their ability to function and increase their need for prescription pain relievers.⁸

Since pain management is crucial for patients with CAD and pain and spasm have a synergistic relationship, the purpose of this essay is to examine how post-procedural access-site heating—a noninvasive, localized technique free from systematic complications—affects the amount of pain experienced and the frequency of bleeding events at the site of the radial sheath following catheterization.

METHODS

Study Design

This prospective, randomized clinical trial aimed to investigate the impact of local forearm heating on pain intensity, sympathetic response, and hemorrhage in patients undergoing radial artery cardiac catheterization. The study was conducted at Rouhani Hospital, Babol, Iran, between July and October 2022.

Patient Population

Patients eligible for inclusion were between the ages of 18 and 65 years and were scheduled to undergo non-emergency cardiac catheterization via radial artery access. Patients provided informed consent and completed a comprehensive demographic questionnaire. Medical history data were retrieved from the patients' medical records. Exclusion criteria included a history of paralysis or hemiparesis, prior surgical procedures on the hands, previous cardiac catheterization via radial artery access, a history of peripheral vascular disease or neuropathy, a previous mastectomy, and the presence of a vascular fistula.

Randomization

Eligible patients were randomly allocated to 1 of 2 groups using a 1 : 1 ratio: the experimental group, which received local forearm heating, and the control group, which received no intervention.

Trans-radial Access Procedure

The access site was sedated with 1% lidocaine and sterilized percutaneously. Trans-radial access was accomplished using 5F or 6F sheaths. Each patient received 200 µg of intra-arterial nitroglycerin via an introducer sheath. Unfractionated heparin (UFH) (5000 IU) was given to individuals who were scheduled for diagnostic angiography through the arterial sheath. Based on the patient's weight,

an extra bolus of UFH was administered for urgent percutaneous coronary procedures (PCI). The guiding catheter was implanted after 100 IU/Kg UFH was administered through the sheath for elective PCIs. The doctor's recommendation was subsequently followed by intravenous injection of additional boluses. All cardiac catheterization procedures were performed by an experienced interventional cardiologist in both the experimental and control groups. All sheaths were retrieved after the half-life of the last prescribed dose of heparin, which occurred 90 minutes after the last heparin injection. Prior to the removal of the sheath, patients in the experimental group received local forearm heating using a Warm-Tach device for a duration of 3 minutes. Local heat was administered through a warm air stream with temperatures maintained at 35°C-45°C, originating from a distance of 20-30 cm from the patient's forearm. The removal of the sheath was conducted by a trained catheterization laboratory nurse. Following the procedure, all patients underwent an examination to assess the patency of the radial artery by checking for the presence of a radial pulse.

Data Collection

The following parameters were recorded at 3 distinct time points: before the application of local heat, immediately after sheath removal, and 1 hour after sheath removal for both the experimental and control groups:

- Pain intensity: Pain levels were assessed using the Visual Analog Scale (VAS). The VAS is a graded scale ranging from 0-10, with divisions into scores zero, 1-3, 4-6, and 7-10 representing "no pain," "mild pain," "moderate pain," and "severe pain," respectively.⁹
- Sympathetic response: Sympathetic response was evaluated through the measurement of systolic and diastolic blood pressure as well as heart rate.
- Hemorrhage assessment: Incidence and extent of hematoma, bleeding, and ecchymosis was meticulously documented.

Statistical Analysis

Data analysis was conducted using IBM SPSS Statistics version 24 (IBM SPSS, Inc., Chicago, Ill, USA). Quantitative results, including age, height, weight, and others, were presented as mean ± SD, while qualitative data, such as sex, level of education, and occupation, were expressed as percentages. The independent 2-sample *t*-test was employed for comparing the means of quantitative variables between the experimental and control groups. The nonparametric Kolmogorov-Smirnov test was applied to examine the normality distribution of quantitative variables. The test indicated that the presumption of normality was met ($P > .05$). The chi-square test was utilized to compare the frequency of qualitative variables between the 2 groups. Hemodynamic variables (systolic and diastolic blood pressure, heart rate) and average pain scores were subjected to 2-way repeated measures analysis of variance (ANOVA) for comparison between the experimental and control groups at the 3 different time points. The significance level for all statistical tests was set at 0.05.

HIGHLIGHTS

- Trans-radial coronary intervention (TCI) offers minimally invasive cardiac catheterization.
- Forearm hematoma is a rare TCI complication.
- Local heat reduces pain and vascular spasms.
- Local heat is a safe and effective addition to pain management.
- Local heat has minimal impact on hemodynamics and complications.

Clinical Trial Registration

This study received approval from the Iranian Registry of Clinical Trials (IRCT) under registration number IRCT20220521054951N1.

The research and content presented in this manuscript were developed without the utilization of artificial intelligence.

RESULTS

A total of 100 patients who underwent radial artery cardiac catheterization, evenly distributed into 2 groups: the intervention group and the control group, each comprising 50 patients. However, 8 patients were subsequently excluded from the study, 3 from the intervention group, and 5 from the control group due to the specified exclusion criteria. Both groups exhibited strikingly comparable baseline characteristics and demographic profiles, with the notable exception of a significant difference in weight favoring the control group (Table 1). Additionally, an extensive examination of the attributes related to the cardiac catheterization procedure revealed no statistically significant differences between the 2 groups, as illustrated in Table 2. It is noteworthy that all patients exhibited postprocedural proper radial pulse, indicating maintained patency.

Primary Outcomes

Table 3 illustrates a noteworthy distinction in average pain scores between the intervention and control groups upon removal of the radial sheath, with a statistically significant difference ($P = .009$) (Table 3). However, 1 hour post removal, there was no statistically significant variance in mean pain scores between the 2 groups ($P = .057$). Figure 1 shows a significant reduction in the average pain score slope for the intervention group, from pre-removal to immediate post-removal (Figure 1). Conversely, the control group exhibits a marginal increase during the same period. Encouragingly, both groups demonstrate a declining slope in the hour following sheath

Table 1. Comparative Analysis of Baseline and Demographic Parameters

Variables	Intervention Group (n = 47)	Control Group (n = 45)	P
Sex			.65
Men	21 (44.7%)	18 (40.0%)	
Women	26 (55.3%)	27 (60.0%)	
Body mass index (kg/m ²)	27.93 ± 3.04	27.06 ± 3.38	.198
Underlying disease			.859
Nothing	10 (21.3%)	9 (20.0%)	
High blood pressure	10 (21.3%)	13 (28.9%)	
Hyperlipidemia	11 (23.4%)	10 (22.2%)	
More than 1 disease	14 (29.8%)	10 (22.2%)	
Other*	2 (4.3%)	3 (6.7%)	
Smoking	7 (14.9%)	9 (20.0%)	.518

Data are presented as mean ± SD for quantitative variables and as number (percentage) for qualitative variables.

*Other underlying diseases include chronic kidney diseases and hypothyroidism.

Table 2. Comparative Analysis of Cardiac Catheterization Procedure's Characteristics

Variables	Intervention Group (n = 47)	Control Group (n = 45)	P
Wrist circumference (cm)	18.34 ± 1.51	18.24 ± 1.15	.733
Procedure type			.348
Angiography	29 (61.7%)	35 (77.8%)	
Angioplasty	8 (17.0%)	4 (8.9%)	
Simultaneous CAG and PCI	10 (21.3%)	6 (13.3%)	
Complications in procedure			.24
Nothing	5 (10.6%)	7 (15.6%)	
Arterial tortuosity	35 (74.5%)	27 (60%)	
Spasm	7 (14.9%)	11 (24.4%)	
Catheter replacement frequency			.331
Once	21 (44.7%)	17 (37.8%)	
Twice	16 (34%)	18 (40%)	
Three times	10 (21.3%)	10 (22.2%)	
Puncture frequency			.781
Once	9 (61.7%)	35 (77.8%)	
Twice	8 (17%)	4 (8.9%)	
Three times	10 (21.3%)	6 (13.3%)	

Data are presented as mean ± SD for quantitative variables and as number (percentage) for qualitative variables.

CAG, coronary angiography; PCI, percutaneous coronary intervention.

removal, underscoring the significant impact of local forearm heating during the time intervals leading up to and immediately following sheath removal.

Secondary Outcomes

Based on the comprehensive analysis presented in Table 4, it has been determined that there exists no statistically significant differentiation ($P < .05$) in the mean hemodynamic parameters observed within both groups at pre-procedure, immediate post-procedure, and one-hour post-procedure time points. The outcomes derived from the ANOVA test substantiate the absence of a statistically significant interaction between the grouping variable and time concerning systolic blood pressure (mm Hg) ($F = 1.408, P = .247$) (Figure 2). Furthermore, the findings pertaining to diastolic blood pressure (mm Hg) ($F = 0.582, P = .560$) (Figure 3) and heart rate

Table 3. Comparison of the Average Pain Score Before, Immediately, and 1 Hour After the Radial Sheath Removal

Time	Intervention Group (n = 47)	Control Group (n = 45)	P
Before the sheath removal	6.04 ± 2.96	4.62 ± 2.71	.019
Immediately after the sheath removal	4.15 ± 2.73	5.84 ± 3.34	.009
An hour after the sheath removal	2.17 ± 2.21	3.00 ± 1.91	.057

Data are presented as mean ± SD.

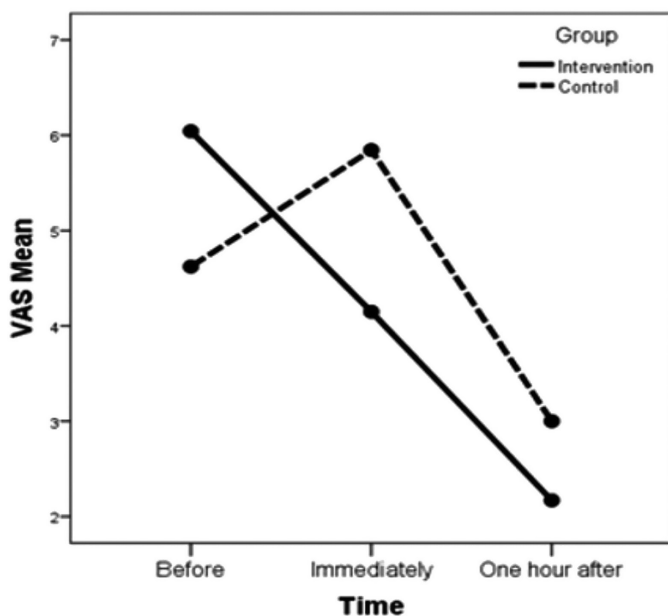


Figure 1. The average pain score according to the studied groups in patients undergoing cardiac catheterization through the radial artery across the period.

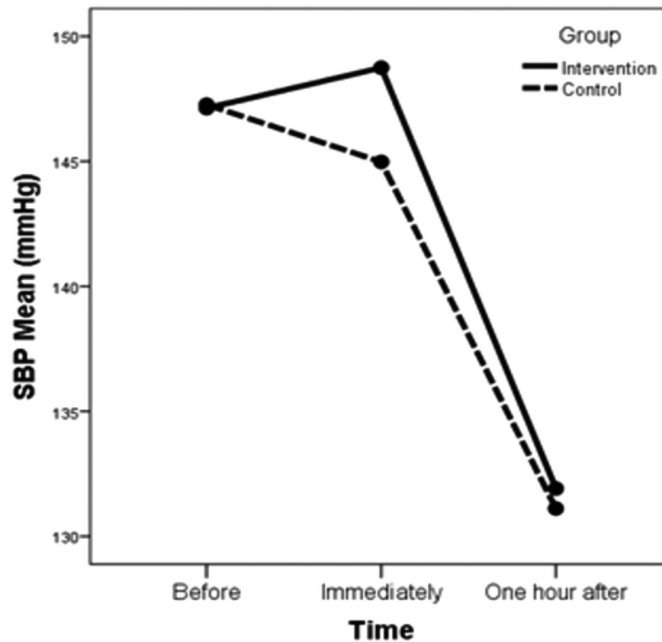


Figure 2. Mean systolic blood pressure (mm Hg) according to the study groups in patients undergoing radial artery cardiac catheterization.

(beats per minute) ($F=0.289, P=.749$) (Figure 4) were uniformly non-disparate, indicating a lack of significant interaction. Collectively, these results signify that the intervention involving local forearm heating during radial sheath removal did not impart a statistically significant impact on the hemodynamic parameters under investigation. The investigations additionally revealed a lack of instances involving bleeding or hematoma within either of the study groups. Furthermore, the data revealed that among the patients, 7 individuals (14.9%) in the intervention group and 5 (11.1%) in the control group reported instances of ecchymosis. Notably, the chi-square test showed no statistically significant difference in

the occurrence of ecchymosis between the 2 study groups ($P=.590$).

DISCUSSION

The general findings of our study demonstrate that post-procedural local forearm heating is an effective intervention for reducing pain intensity following sheath removal, without significant adverse effects on hemodynamic parameters or

Table 4. Comparison of the Average Hemodynamic Parameters Before, Immediately, and 1 Hour After the Radial Sheath Removal

Time	Intervention Group (n=47)	Control Group (n=45)	P
Systolic blood pressure (mm Hg)			
Before	147.13 ± 22.48	147.27 ± 22.06	.976
Immediately	148.74 ± 20.04	144.98 ± 19.22	.360
One hour later	131.91 ± 18.37	131.11 ± 16.95	.828
Diastolic blood pressure (mm Hg)			
Before	77.07 ± 12.44	75.69 ± 11.47	.589
Immediately	79.00 ± 10.39	76.53 ± 12.68	.309
One hour later	75.85 ± 8.74	75.73 ± 9.10	.950
Heart rate (number per minute)			
Before	71.51 ± 10.89	74.71 ± 14.53	.234
Immediately	71.51 ± 11.50	74.91 ± 15.44	.233
One hour later	68.45 ± 9.58	70.87 ± 11.45	.274

The data are presented as mean ± SD.

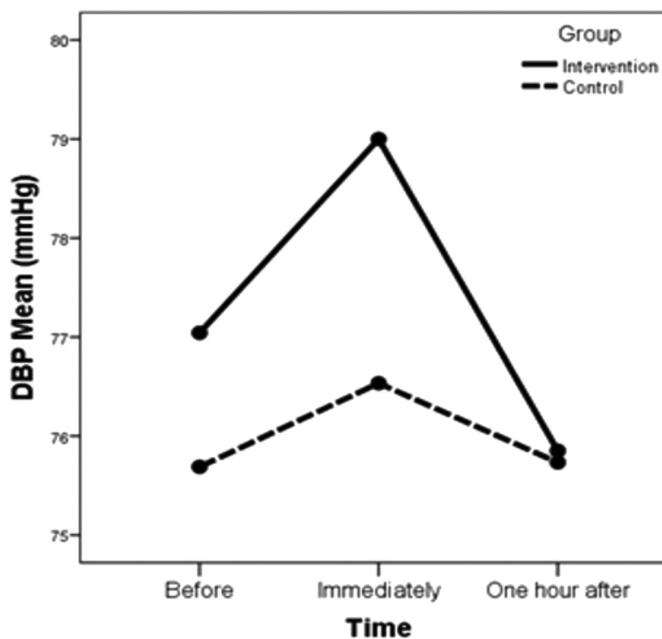


Figure 3. Mean diastolic blood pressure (mm Hg) according to the study groups in patients undergoing radial artery cardiac catheterization.

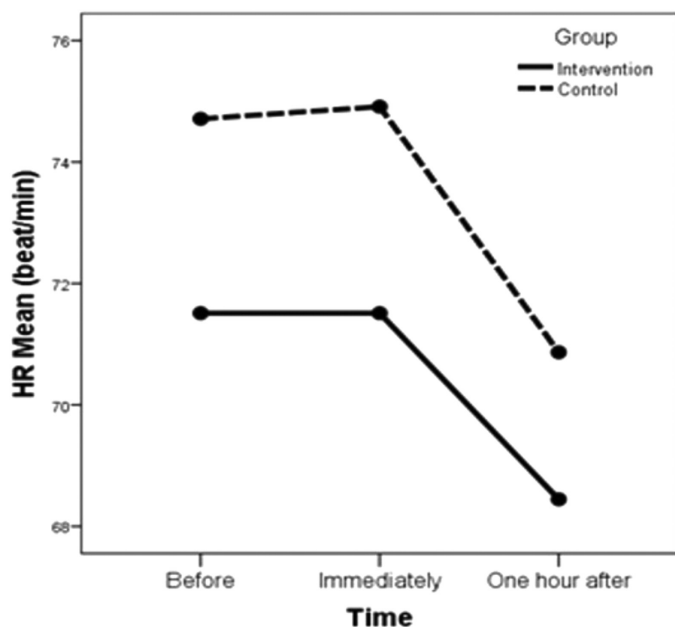


Figure 4. Mean heart rate (beats per minute) according to the study groups in patients undergoing radial artery cardiac catheterization.

procedural outcomes. Trans-radial coronary intervention is a preferred, less invasive procedure due to its minimal discomfort, early ambulation, and shorter hospital-stay duration.¹⁰ However, complications like radial artery spasm or occlusion at the access site and forearm hematoma can arise during or after TCI. While the incidence of forearm hematoma after TCI ranges from 0.3%-33%, the incidence of large hematoma requiring blood transfusions or vascular surgery is negligible.^{11,12} Non-pharmacological approaches such as forearm heating inducing hyperemia and dilation of the radial artery could potentially relieve radial artery spasm.¹³

Experiencing a spasm in the radial artery during puncture or after removing the sheath can cause significant discomfort and severe pain.¹⁴ It's important to note that pain and spasms are closely linked, and ignoring pain relief can lead to increased catecholamine secretion, resulting in spasms, increased heart rate, blood pressure, respiratory rate, myocardial oxygen demand, and reduced respiratory volume.^{4,7} Based on the importance of non-pharmacological methods for pain relief, heat therapy can effectively reduce pain and vascular spasms during radial sheath removal after cardiac catheterization. It is a safe and easy to administer method that can be a valuable addition to pain management protocols in clinical settings.¹⁵ For the treatment of pain, heat therapy can have 2 separate effects: either on the muscles or on the skin's surface tissues.¹⁶ Thermotherapy reduces sympathetic activity, vasodilation, increases blood flow to the inflamed and injured area, and eliminates toxic metabolites from the affected area such histamine and bradykinin.¹⁷ Our study's results offer important new information about the possible advantages and drawbacks of using post-procedural heat at the radial access site as an intervention during radial sheath retrieval. The results revealed the

intervention group exhibited a substantial reduction in pain intensity compared to the control group. This suggests that local forearm heat effectively mitigated pain after sheath removal. Notably, both groups displayed a similar decline in pain scores within the hour after sheath removal, indicating that local forearm heating primarily influenced immediate post-removal pain. Furthermore, our finding indicated no statistically significant difference in the average change in hemodynamic parameters throughout the study period. This suggests that local forearm heating had no notable impact on hemodynamic parameters, underscoring the stability of cardiovascular parameters during the studied phases.

One of the most feared consequences is vascular access site bleeding, which is exacerbated by the use of anticoagulants and platelet glycoprotein inhibitors.¹⁸ There were no instances of bleeding or hematoma in either group in our study, indicating the safety and efficacy of the cardiac catheterization procedure via the radial artery in both intervention and control groups.

Study Limitations

The study's limitations include a small sample size of 100 patients and a single-center design, potentially limiting broader applicability. It primarily focused on short-term outcomes, lacking assessment of long-term effects. Subjective pain scales and qualitative measures for hemorrhage might lack precision. While no immediate adverse effects were reported, potential rare or delayed reactions were not thoroughly explored within the study's scope.

CONCLUSION

In conclusion, the application of local forearm heat significantly reduced pain scores after arterial sheath removal in the intervention group. However, this intervention did not exert a notable effect on hemodynamic parameters or subsequent outcomes such as hematoma, bleeding, and ecchymosis. These findings suggest that post-procedural local forearm heating can be a valuable intervention in enhancing patient comfort after a cardiac catheterization procedure. Further research with a larger sample size and refined methodologies is warranted to corroborate these findings and explore the potential for integrating local forearm heating as a routine practice in cardiac catheterization procedures.

Ethics Committee Approval: The project was found to be in accordance with the ethical principles and the national norms and standards for conducting Medical Research in Iran (by Rajaie Heart Center Ethics Committee, decision date: July 16, 2022, decision number: IR.RHC.REC.1401.049).

Informed Consent: Written informed consent was obtained from the patients.

Peer-review: Externally peer-reviewed.

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A.Z.; Data Collection and/or Processing – A.S., F.S.; Analysis and/or Interpretation – M.S., P.T.; Literature Search – A.S., F.S.; Writing – A.S., Y.D.; Critical Review – P.T., A.Z.

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