Journal of Clinical and Nursing Research, 2026, Volume 10, Issue 1
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Examining the Impact of Heparin-Free Dialysis Supplemented with Infrared Lamp Irradiation on Coagulation in Dialyzers

Qin Chen

Suzhou Wuzhong People's Hospital, Suzhou 215000, Jiangsu, China

Abstract: *Objective*: To investigate the effects of infrared lamp irradiation therapy on the risk of arteriovenous fistula thrombosis in patients undergoing heparin-free dialysis and those receiving appropriate reductions in heparin anticoagulation dosage during dialysis. *Methods*: This study was conducted from January 1, 2021, to December 31, 2021, involving 19 patients who regularly underwent heparin-free dialysis for more than three months at our hospital, totaling 70 patient encounters. Each patient underwent heparin-free dialysis for more than two cycles during the experimental period. The study employed a self-control design. Prior to the experiment, an experienced medical team established an emergency management group and formulated relevant emergency measures, ensuring the long-term stability of patients' vital signs before enrollment. Patients requiring heparin-free dialysis as per medical advice underwent the procedure according to the treatment manual without additional interventions. During the second heparin-free dialysis session within the experimental period, patients received 40 minutes of infrared lamp irradiation as an adjunctive therapy during the dialysis process. The study observed coagulation in the dialyzer, blood biochemical indicators, the occurrence of adverse reactions, and patient satisfaction during treatment. *Results:* The use of heparin-free dialysis combined with infrared irradiation therapy resulted in better coagulation outcomes compared to heparin-free dialysis alone ($p < 0.05$). There was no statistically significant difference in blood biochemical indicators between patients receiving heparin-free dialysis combined with infrared irradiation therapy and those receiving heparin-free dialysis alone ($p > 0.05$). There was no statistically significant difference in the number of patients experiencing adverse clinical symptoms such as angina, dizziness, and lower limb cramps, leading to treatment interruption, between those receiving heparin-free dialysis combined with infrared therapy and those receiving heparin-free dialysis alone ($p > 0.05$). Patient satisfaction was higher among those receiving heparin-free dialysis combined with infrared therapy compared to those receiving heparin-free dialysis alone ($p < 0.05$). *Conclusion:* The use of infrared lamp irradiation therapy as an adjunct to heparin-free dialysis can reduce the risk of coagulation to a certain extent without affecting the stability of core blood biochemical indicators in patients. It also reduces the incidence of clinical adverse reactions caused by coagulation, demonstrating good safety and improving patient satisfaction.

Keywords: Heparin-free dialysis; Infrared lamp; Heparin anticoagulation

Online publication: Feb 11, 2026

1. Introduction

Heparin is the most commonly used anticoagulant in extracorporeal circulation for blood purification techniques. However, with the increasing number of uremic patients in recent years, the number of cases with active bleeding has gradually risen, leading to more frequent clinical use of heparin-free dialysis [1]. Heparin-free dialysis primarily reduces the risk of coagulation by increasing blood flow velocity and regularly flushing the circuit with physiological saline. Nevertheless, in practice, it still faces the issue of a high incidence of coagulation in the extracorporeal circulation circuit, especially within the dialyzer. Moderate to severe coagulation not only decreases dialyzer efficiency and leads to inadequate treatment but may also cause blood loss, increase medical costs, and even endanger patient safety due to frequent circuit replacements or premature treatment termination [2]. Far-infrared rays are a type of electromagnetic wave with a wavelength range of 3–1000 μm, possessing penetrability and thermal effects [3]. Studies have shown that irradiation with far-infrared rays of specific wavelengths in the field of cardiovascular medicine exhibits multiple biological effects, such as improving vascular endothelial function, promoting microcirculation, inhibiting platelet aggregation, and reducing inflammatory responses [4]. However, there are few reports both domestically and internationally on the use of far-infrared irradiation as an adjunctive physical anticoagulant method in heparin-free dialysis, directly applied to the extracorporeal circulation circuit and the patient's limbs to reduce coagulation within the circuit. At our hospital's hemodialysis center, under the premise of stable patient conditions, we conducted a study comparing heparin-free dialysis with and without adjunctive infrared therapy. The results indicated that adjunctive infrared lamp irradiation therapy could, to a certain extent, reduce the risk of coagulation and the incidence of clinical adverse reactions caused by coagulation. The report is as follows.

2. Materials and methods

2.1. General information

The study subjects were 19 patients who underwent regular dialysis at our hospital for more than three months from January 1, 2021, to December 31, 2021, and required heparin-free dialysis.

2.1.1. Inclusion criteria

(1) Presence of active bleeding symptoms or high risk of bleeding;
(2) No use of any procoagulant medications in the recent period;
(3) No interventions that may promote coagulation, such as blood transfusions or intravenous infusions, during hemodialysis procedures;
(4) Excellent vascular access status, with blood flow rates through autogenous arteriovenous fistulas or central venous catheters stably reaching 240 mL/min.

2.1.2. Exclusion criteria

(1) Age under 18 years old;
(2) Individuals unable to complete the entire treatment regimen;
(3) Presence of broken skin, ulcers, or photosensitive lesions at the irradiation site;
(4) Platelet count exceeding the upper limit or falling below the lower limit of the normal reference range;
(5) Patients with diabetic nephropathy and multiple organ failure;

(6) Patients with insufficient blood flow velocity to meet the basic requirements for hemodialysis operation.

2.1.3. Study groups

Among the 19 patients, there were 11 males and 8 females; their ages ranged from 22 to 75 years, with an average age of (61.02 ± 14.76) years; the primary diseases included diabetic nephropathy (4 cases), polycystic kidney disease (2 cases), hypertensive nephropathy (6 cases), lupus nephritis (4 cases), and chronic glomerulonephritis (3 cases). Among the 19 patients, there were 2 cases of gastrointestinal bleeding, 12 cases of gingival bleeding, 1 case of skin and mucous membrane bleeding, and 4 cases were in menstruation. All patients underwent heparin-free hemodialysis three times within one week, with the treatment cycle determined according to medical advice. A description of the relevant research conducted on patients who met the inclusion criteria was provided, and both patients and their families were fully informed of the research risks and benefits and signed informed consent forms. This study was approved by the hospital's ethics committee.

2.2. Methods

Before the experiment, an emergency management team was established by experienced medical staff, and relevant emergency measures were formulated in advance to ensure long-term stability of vital signs in patients before enrollment. For patients undergoing heparin-free hemodialysis, no additional treatment was administered during the first cycle of heparin-free hemodialysis as per medical advice; during the second cycle of heparin-free hemodialysis, patients received 40 minutes of infrared lamp irradiation as an adjunctive therapy during dialysis, as per medical advice. During the experiment, close attention was paid to the patients' mental state and whether they exhibited symptoms such as angina, dizziness, and lower limb cramps, with records made accordingly. Biochemical examination indicators were monitored monthly throughout the experimental period, with hemoglobin and platelet data collected for each group of patients. The usage status of arteriovenous fistulas was assessed on a monthly basis.

2.3. Evaluation indicators

(1) Observe and compare the coagulation occurrence in the dialyzer and venous chamber, as well as the completion of dialysis procedures, following the implementation of two different flushing protocols for heparin-free dialysis. The grading criteria for evaluating the degree of coagulation in the dialysis circuit and dialyzer are as follows. Grade A: No obvious signs of coagulation, or only a small amount of fibrous cord-like coagulation is observed, with no other adverse events occurring. Grade B: Local coagulation or bundled coagulation clots are present, accompanied by mild dizziness, with no other adverse events occurring. Grade C: Relatively obvious coagulation or coagulation in more than half of the fibers is observed in the dialyzer, with some patients experiencing symptoms such as angina, dizziness, and lower limb cramps. Grade D: Severe coagulation necessitates the replacement of the dialyzer, accompanied by symptoms such as angina, dizziness, and lower limb cramps.

(2) Observe and compare changes in patients' blood biochemical indicators. Collect 5 mL of peripheral venous blood from patients and send it to the hospital's laboratory for the detection of hemoglobin, blood phosphorus, blood creatinine, and blood potassium levels using an automatic biochemical analyzer.

(3) Observe and compare the occurrence of adverse reactions in patients, including angina, dizziness, and lower limb cramps.

(4) Patient satisfaction was assessed using a self-designed satisfaction questionnaire from our hospital.

2.4. Statistical methods

Data were analyzed using SPSS 23.0 statistical software, with a significance level set at $p < 0.05$.

3. Results

3.1. Comparison of coagulation status

The coagulation status was significantly better in patients treated with heparin-free dialysis combined with infrared irradiation compared to those treated with heparin-free dialysis alone ($p < 0.05$), as shown in **Table 1**.

Table 1. Comparison of coagulation status

	Frequency of coagulation occurrence			Total number of cases	Overall clotting proportion
	Grade	Frequency	Total frequency of coagulation		
No heparin	A	98	16	19	14.0%
	B	11			
	C	5			
	D	0			
No heparin + infrared	A	105	9	19	7.9%
	B	6			
	C	3			
	D	0			

3.2. Comparison of changes in blood biochemical indicators among patients

There was no statistically significant difference in the levels of blood biochemical indicators between patients treated with heparin-free dialysis combined with infrared irradiation and those treated with heparin-free dialysis alone ($p > 0.05$), as shown in **Table 2**.

Table 2. Comparison of changes in blood biochemical indicators among patients

	Heparin-free protocol	Heparin-free + infrared protocol	Within-subject max-min difference
Hemoglobin (g/L)	81–146 g/L	75–155 g/L	-19 to +23
Phosphorus (mmol/L)	1.90–5.61 μmmol/L	1.93–4.64 μmmol/L	-0.51 to +0.55
Pre-dialysis creatinine (μmol/L)	930–2300 μmmol/L	900–2340 μmmol/L	-200 to +240
Potassium (mmol/L)	4.9–6.8 mmol/L	4.7–6.8 mmol/L	-1.2 to +1.3

3.3. Comparison of adverse reactions during dialysis among patients

There was no statistically significant difference in the number of patients experiencing adverse clinical symptoms or treatment interruptions between those treated with heparin-free dialysis combined with infrared irradiation and those treated with heparin-free dialysis alone ($p > 0.05$), as shown in **Table 3**.

Table 3. Comparison of adverse reactions during dialysis among patients

Adverse symptom	Heparin-free protocol (n = 112)	Heparin-free + infrared protocol (n = 114)
Angina Pectoris	0	0
Dizziness/Vertigo	4	4
Lower limb cramps	5	5
Treatment interruption	1	0
Total frequency of adverse symptoms	10	9
Overall incidence of adverse symptoms	8.9%	7.9%

3.4. Comparison of patient satisfaction

Patient satisfaction was significantly higher in those treated with heparin-free dialysis combined with infrared irradiation compared to those treated with heparin-free dialysis alone ($p < 0.05$), as shown in **Table 4**.

Table 4. Comparison of patient satisfaction

Protocol	Total cases (n)	Satisfaction rate
Heparin-free	19	64%
Heparin-free + infrared	19	75%

4. Discussion

Heparin-free dialysis is an important dialysis modality for end-stage renal disease (ESRD) patients with a high risk of bleeding. The coagulation status of patients undergoing heparin-free dialysis poses significant risks to their life and health safety, as well as presenting substantial challenges to healthcare providers in terms of treatment [5]. Heparin-based anticoagulants are commonly used in clinical dialysis; however, for patients with high bleeding risks, such as those with active bleeding, severe coagulation disorders, or recent surgery, the use of heparin drugs significantly increases the risk of bleeding. Therefore, heparin-free dialysis becomes the preferred dialysis method for such patients [6]. Nevertheless, during heparin-free dialysis, the contact between blood and artificial materials such as dialysis circuits and filters can easily activate the endogenous coagulation pathway, leading to platelet adhesion, aggregation, and fibrin deposition, which in turn can cause adverse events such as filter clotting and circuit coagulation. These issues not only affect the adequacy of dialysis but may also increase the patient's need for blood transfusions and medical expenses, and even endanger the patient's life [7]. How to effectively prevent coagulation during heparin-free dialysis while avoiding bleeding risks remains a pressing clinical challenge.

In recent years, the application of physical interventions in vascular protection and coagulation management for hemodialysis patients has garnered attention. Infrared lamp irradiation, as a non-invasive physical therapy method, emits far-infrared rays that can penetrate skin tissue, improve local blood circulation, dilate blood vessels, and inhibit platelet aggregation while regulating the activity of coagulation factors. It has demonstrated certain effects in the maintenance of arteriovenous fistulas and the prevention of thrombosis [8]. Studies have confirmed that infrared lamp irradiation can increase the blood flow of arteriovenous fistulas and reduce the risk of stenosis and thrombosis in fistulas [9]. The results of this study indicate that heparin-free dialysis combined with infrared irradiation is superior to heparin-free dialysis alone in terms of coagulation status ($p < 0.05$). The anticoagulant

mechanism of infrared lamp irradiation may be related to its physical properties: the far-infrared rays emitted by the infrared lamp can penetrate tissues, dilate blood vessels through thermal effects, improve local blood circulation, reduce blood viscosity, and decrease platelet aggregation. Additionally, far-infrared rays can regulate the activity of coagulation factors and inhibit the activation of the coagulation cascade, thereby delaying the coagulation process.

There was no statistically significant difference in biochemical indicator levels between patients undergoing heparin-free dialysis combined with infrared therapy and those undergoing heparin-free dialysis alone ($p > 0.05$). The stability of hemoglobin suggests that the intervention did not affect the patient's hematopoietic function or iron metabolism balance, avoiding the potential risk of worsening anemia and increasing cardiovascular complications due to the intervention. The stable levels of blood phosphorus, serum creatinine, and blood potassium indicate that infrared lamp irradiation did not interfere with the solute diffusion and convection clearance mechanisms during dialysis, nor did it affect the residual renal excretion function. By regulating the activity of coagulation factors and inhibiting platelet aggregation through far-infrared rays, the intervention did not involve pathways related to the hematopoietic system or renal solute transport, and therefore did not have adverse effects on the aforementioned core blood biochemical indicators. There was no statistically significant difference in the occurrence of adverse clinical symptoms and treatment interruption between patients undergoing heparin-free dialysis combined with infrared therapy and those undergoing heparin-free dialysis alone ($p > 0.05$), indicating that infrared irradiation therapy does not affect patient treatment and does not increase the incidence of adverse reactions, demonstrating good safety. Patients who underwent heparin-free dialysis supplemented with infrared therapy reported higher satisfaction levels compared to those who received heparin-free dialysis alone ($p < 0.05$). The reduction in coagulation-related events and adverse reactions directly enhanced the comfort of the dialysis process, alleviating discomfort caused by filter clotting, increased venous pressure, muscle cramps, and other issues, without affecting the adequacy of dialysis, the stability of core blood biochemical indicators, or increasing adverse reactions, thereby improving patient satisfaction. Although the duration of infrared irradiation used as an adjunctive therapy in this study exceeded the amounts reported in current domestic literature [10].

5. Conclusion

In summary, adjunctive treatment with infrared lamp irradiation can, to a certain extent, reduce the risk of coagulation without affecting the stability of patients' core blood biochemical indicators. It also lowers the incidence of clinical adverse reactions caused by coagulation, thereby improving patient satisfaction and demonstrating good safety and clinical value. However, this study has certain limitations: firstly, the sample size is relatively small, and it is a single-center study, which may introduce selection bias and limit the generalizability of the findings. Secondly, the observation period is relatively short, making it impossible to evaluate the long-term effects of infrared lamp irradiation. Additionally, the molecular mechanisms by which infrared lamp irradiation affects coagulation function, such as its impact on coagulation factor gene expression and platelet activation markers, were not thoroughly explored. Therefore, future research should involve multi-center, large-sample, long-term follow-up clinical studies to further validate the effects of infrared lamp irradiation and delve deeper into its mechanisms of action, providing more robust evidence for its clinical application.

Funding

2023 Hospital-Level Scientific Research and New Technology Project Initiation of Wuzhong People's Hospital (Project No.: 2023yjxjs05)

Disclosure statement

The author declares no conflict of interest.

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