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The effect of hemodialysis with cool dialysate on nausea in hemodialysis patients: A randomized clinical trial

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Abstract

Background and Aims: Experiencing nausea leads to decreased self-esteem and social isolation in hemodialysis patients and affects all aspects of their quality of life. Nausea and vomiting make hemodialysis unpleasant for patients leading to premature termination of hemodialysis. Therefore, based on this necessity, the present study was conducted to determine the effect of hemodialysis with cool dialysate on nausea in hemodialysis patients.

Methods: In this clinical trial, 60 eligible patients receiving hemodialysis were randomly assigned to the control (30 participants) and intervention (30 participants) groups. In the control group, the patients received standard hemodialysis (37°C) for three sessions. Simultaneously, patients in the intervention group received hemodialysis with a cold solution (of 36°C) for three sessions. The patients' nausea and shivering rates were measured using the visual analog scale and the shivering standard assessment scale, respectively. Both groups were evaluated before and after 1 week of intervention. The study did not include blinding. The trial has been registered in the Iranian Registry of Clinical Trials (IRCT) with the number IRCT20200530047597N1. The present study was financially supported by Kermanshah University of Medical Sciences, Kermanshah, Iran (no. 990220). Data were analyzed using SPSS-25 software.

Findings: The independent *t* test showed no statistically significant difference between the two control and experimental groups regarding the nausea rate in the three evaluation times ($p < 0.05$). Nevertheless, nausea severity decreased significantly after the intervention in the two groups. However, the rate of nausea in the intervention group with cold solution decreased more compared to the control group. Moreover, no patient in the intervention group experienced shivering during hemodialysis with a cool dialysate.

Conclusion: According to the results of this study, it can be stated that the use of cold hemodialysis to control nausea in patients undergoing hemodialysis requires

further studies and can be recommended as a nonpharmacological treatment to manage the treatment costs in case of efficiency.

KEYWORDS
hemodialysis solutions, kidney failure, nausea

1 | INTRODUCTION

On the threshold of the 21st century, the prevalence of chronic diseases is the most prominent event faced by societies and healthcare personnel.[1,2] One of the diseases that causes considerable stress for the patient is end-stage renal disease (ESRD).[3,4] Chronic renal failure refers to a significant, continuous, and irreversible decline in the number of nephrons in which the kidney is no longer able to remove metabolic wastes and retains fluids and electrolytes. This failure leads to increased blood urea syndrome.[5,6] The prevalence of chronic kidney disease and the number of patients undergoing hemodialysis have been increasing dramatically in the last two decades, particularly in developing countries.[7,8] Controlling and treating the disease is of particular importance.[3,9] In the final stage of chronic kidney failure, it is indispensable to use alternative methods to preserve life. Such alternative treatments, including hemodialysis, peritoneal dialysis, kidney transplant, and hemodialysis as one of the most common methods, can compensate for the lost normal function of the kidneys.[5,10] Hemodialysis is a process to remove excess fluid and uremic waste products from the body, which is used acutely in needy patients from several days to several weeks and chronically in patients with ESRD.[11,12] This method is the most common treatment among alternative kidney therapeutic methods in patients with kidney failure, which is used in Iran and worldwide.

More than one million people worldwide continue to live through dialysis. With broad access to dialysis, the lives of hundreds of thousands of patients with end-stage kidney disease have been prolonged.[3] However, despite the vital role of hemodialysis in preserving patients' lives, it is unable to alleviate all the complications caused by kidney dysfunction. Accordingly, various complications are observed in patients undergoing hemodialysis.[13,14] Common adverse effects of hemodialysis include hypotension, muscle cramps, nausea and vomiting, headache, chest pain, back pain, fever, and shivering, with nausea and vomiting occurring in more than 25% of hemodialysis patients.[15] The prevalence of nausea and vomiting was reported to be 9.8%–18.2%. Despite this, nausea and vomiting in Iran have been reported to be more prevalent and above 25.8%. According to the study by Asgari et al., the prevalence of nausea in hemodialysis patients was 28.3%.[16]

Nausea and vomiting are caused by various factors such as a rapid drop in blood pressure and urea during hemodialysis, anxiety and psychological effects of this therapeutic method, balance disorders, patient's diet, specific medication regimen, increased amount of circulating fluids, and early satiety when starting dialysis. Nausea and vomiting limit the duration of hemodialysis and do not allow proper treatment. Experiencing nausea and vomiting leads to patients' decreased self-esteem and social isolation and affects all aspects of their quality of life. Nausea and vomiting make hemodialysis unpleasant for patients leading to premature termination of hemodialysis and causing inadequate and disagreeable hemodialysis despite its high costs. To reduce nausea and vomiting incidence during hemodialysis, normal saline, hypertonic solutions, reduced pump speed of the hemodialysis machine, and antinausea and vomiting medications are used. Since the purpose of hemodialysis is to reduce fluids and electrolytes accumulated in the patient's body during the interval between dialysis sessions, prescribing a large volume of liquids is contrary to the therapeutic function of hemodialysis. In addition, by reducing the machine pump speed, the adequacy of hemodialysis will be dissatisfying. Besides, antinausea and vomiting medications have adverse effects such as dystonic reactions, extrapyramidal symptoms, dizziness, restlessness, fatigue, and drowsiness.[11,17]

On the other hand, numerous nonpharmacological interventions prevent and cure hemodialysis complications, which are satisfactory for the patients and the medical staff, one of which is the cold hemodialysis solution.[7] These interventions have been highlighted due to their simplicity and low cost.[18] During hemodialysis, patients' body temperatureincreases due to the increase in sympathetic stimulation and the decrease in the body's ability to dissipate heat due to the severe contraction of the peripheral vessels caused by the removal of fluids. An increased body temperature commonly leads to vasodilation reflex, increased venous capacity, decreased cardiac output, itching, fatigue, nausea, dizziness, and muscle cramps.[7,11,19]

When cold dialysate is used, heat is exchanged between blood and hemodialysis solution. Therefore, an increase in body temperature and vascular contractions are prevented. A cold hemodialysis solution can prevent the majority of hemodialysis complications. It also increases the efficiency of hemodialysis by increasing the heart and peripheral blood vessels' contraction, reducing the sympathetic nervous system stimulation, improving oxygenation to tissues, and reducing the activity of monocytes.[7,20] Therefore, this method can probably be effective in reducing the nausea rate in hemodialysis patients. Previous studies have shown the efficiency and safety of this method.[7,20] Although there is a possibility of shivering while using cold dialysate, most patients adequately tolerate it.[7,21,22]

According to these studies, the cold hemodialysis solution can help patients feel revitalized after hemodialysis, which plays a positive role in improving patients' general health.[7] Today, nephrologists have a consensus that low temperatures of the hemodialysis solution are beneficial in many cases. However, despite the

tremendous advances in hemodialysis technology, too little attention has been paid to the temperature of the hemodialysis solution in patients undergoing long-term hemodialysis.[7,21]

Numerous studies have been conducted on the effect of cold hemodialysis; however, the majority of them have measured the effect of cold hemodialysis on the hemodynamic changes of the body during hemodialysis and the prevention of hypotension.[23] Some of these studies have shown the effectiveness of the cold hemodialysis solution on the rate of nausea and vomiting in hemodialysis patients. For instance, by investigating the effect of cold hemodialysis solution on the vital signs and comfort of patients undergoing hemodialysis, Borzou et al.[21] concluded that lowering the temperature of the hemodialysis solution reduced the incidence of hypotension and associated symptoms (muscle cramps, nausea, and vomiting).[21]

Therefore, it will be a significant step toward increasing the quality of hemodialysis patients' life and reducing treatment costs if the rate of nausea is reduced by using cold hemodialysis. However, the necessity of conducting a study that specifically investigates the effect of hemodialysis with a cold solution on hemodialysis patients' nausea rate is felt. Therefore, according to the statements mentioned above, the researcher decided to conduct a study to determine the effect of cold dialysate on nausea in hemodialysis patients.

2 | MATERIALS AND METHODS

2.1 | Study design and randomization

This study was a parallel group randomized controlled trial conducted to determine the effect of cold hemodialysis on nausea in hemodialysis patients in Kermanshah, Iran. The allocation ratio in this study was 1:1. To this end, 60 hemodialysis patients in Kermanshah were randomly assigned to one of the two intervention (30 participants) and control (30 participants) groups. To generate a random sequence, block randomization was used. For this purpose, the letters A and B were assigned to the intervention and control groups, respectively. The block size was four individuals, and since the total number of study participants was 60, the number of required blocks was calculated as 15 (60 ÷ 4 = 15) (Supporting Information: Appendix 1).

Afterward, sealed envelopes were used to ensure allocation concealment. The block number and the letter A or B had already been placed inside envelopes, which were opened by the researcher (YO) after writing the participant's name on them.

2.2 | Participants and data collection

Data were collected from July to September 2019, and the participants were selected from the largest teaching hospital located in Kermanshah, western Iran. The researcher visited the study setting daily, in the morning, noon, and evening shifts. Each patient regularly visited the Kermanshah hemodialysis center for hemodialysis in the morning, noon, and evening shifts. In other words, the samples who visited in the morning had a similar visit time the subsequent day, and so did the patients in the afternoon and evening shifts. Inclusion criteria included: the constant pump speed during the study, identical type and ultrafiltration of the membrane in the two study groups, performing hemodialysis three times a week and each time for 3–4 h, a history of hemodialysis at least the past 6 months, the patient's full consent to participate in this study, at least 18 and at most 65 years of age, and no use of antinausea and vomiting medications. Exclusion criteria included: changing the frequency and duration of hemodialysis (a change in the hemodialysis schedule), fever and shivering, death, travel or transfer to other medical centers, and unwillingness to continue cooperation.

2.3 | Ethical considerations

The Institutional Review Board approved this study (Code: 990220). To comply with ethical considerations, after obtaining permission from the Ethics Committee of Kermanshah University of Medical Sciences under the number IR.KUMS.REC.1398.18, the researcher obtained the written informed consent of each participant. Participants were assured that they had the right to withdraw from the study at any stage. It should be noted that this trial has been registered in the Iranian Registry of Clinical Trials (IRCT) under the number IRCT20200530047597N1.

2.4 | Calculation of sample size

According to a pilot study, the minimum sample size required was calculated based on the mean score of nausea, with a confidence level of 95% ($\alpha - 1$), test power of 90% ($\beta - 1$), and other parameters as follows (Figure 1).

The required sample size was estimated based on the nausea index of 16 participants, which was estimated to be 18 participants taking into account 10% of sample attrition. To obtain more accurate results, 30 individuals for each group and a total of 60 individuals were considered.

2.5 | Outcome measurement and intervention implementation

The primary outcome of this study was nausea. In this study, demographic and disease information questionnaires, the visual analog scale (VAS), and the shivering standard assessment scale were used to collect the data. In the first stage, a questionnaire containing all research samples' demographic and disease information, such as gender, age, marital status, education level, weight, nausea, history of smoking, place of residence, underlying disease, duration of kidney failure, and hemodialysis, the temperature of hemodialysis solution, diet, blood pressure before

$$\mu_1 = 4.24$$
$$\mu_2 = 5.96$$
$$\sigma_1 = 1.4$$
$$\sigma_2 = 1.6$$
$$z_{1-\beta} = z_{1-0.1} = z_{0.9} = 1.28$$
$$z_{1-\frac{\alpha}{2}} = z_{1-\frac{0.05}{2}} = z_{0.975} = 1.96$$
$$n = \frac{(z_{1-\frac{\alpha}{2}} + z_{1-\beta})^2 \times (\sigma_1^2 + \sigma_2^2)}{(\mu_1 - \mu_2)^2} = \frac{(z_{0.975} + z_{0.90})^2 \times (1.4^2 + 1.6^2)}{(4.24 - 5.96)^2}$$
$$n = \frac{(1.96 + 1.28)^2 \times (1.96 + 2.56)}{(-1.72)^2} = \frac{(3.24)^2 \times (4.52)}{(2.95)} = \frac{(10.49) \times (4.52)}{(2.95)} = 16.07$$
$$n = 16$$

FIGURE 1 The study formula.

hemodialysis, body temperature before and after hemodialysis, history of kidney transplantation, number of hemodialysis sessions per week, hemodialysis shift, vascular access, type of membrane used, speed of the pump, and serum level of sodium, potassium, urea, and creatinine were completed by the researcher. VAS includes a horizontal line ranging from 0 to 10, with the scores 0 indicating no nausea, 1–3 mild nausea, 4–6 moderate nausea, 7–9 severe nausea, and 10 extremely severe nausea. The validity and reliability of this tool have been investigated in various studies.[5,7,24,25] The rate of patients' nausea was measured in three stages (beginning of hemodialysis, 2 h later, and at the end of hemodialysis). The rate of patients' shivering was also evaluated at the beginning of hemodialysis, 2 h later, and at the end of hemodialysis using the shivering grade (Wrench et al.'s shivering grade).[26–28] In this scale, the scores ranged from 0 to 4, as follows: score 0 = no shivering, 1 = narrowing of peripheral vessels without visible shivering, 2 = visible muscle contractions in only one muscle group, 3 = visible muscle contractions in more than one muscle group, 4 = visible muscle contractions in the whole body (complete shivering).

Patients in the intervention and control groups received hemodialysis for 1 week (three consecutive hemodialysis sessions) with a solution temperature of 36°C and 37°C, respectively. The patients' systolic and diastolic blood pressure was checked before each hemodialysis session using a handheld sphygmomanometer, in a sitting position, on the arm to which an arteriovenous fistula (catheter) was attached, and recorded in the forms prepared in advance and approved by the respected professors of Kermanshah Nursing School. The temporal temperature was checked with a digital thermometer and recorded before hemodialysis each session. The room temperature was 23–24°C under the low airflow.

The parameters during hemodialysis, including blood flow rate, hemodialysis solution flow rate, dialysis membrane, dialysis machine, and dialysis time, were recorded in the first session. In the two following sessions, all conditions were kept constant for both groups except for the temperature. The researcher used the temperature adjustment button on the hemodialysis machine to cool the dialysis solution.

2.6 | Statistical analysis

Data were analyzed using SPSS software version 25. Chi-square test, Fisher's exact test, Yates correction test, and independent *t* test were used to examine the homogeneity of demographic variables between the intervention and control groups. Furthermore, the Kolmogorov–Smirnov test was used to examine the distribution of nausea scale scores. To investigate the changes in the mean of the mentioned scales, repeated measure analysis was used. Moreover, an independent *t* test was used to compare the mean scores of the nausea scale at each time interval. The significance level was set at 0.05 and two-sided tests were used for all analyses.

3 | RESULTS

In the first stage (enrollment), inclusion criteria were examined in 100 individuals undergoing hemodialysis. To this end, the inclusion criteria were examined, and 60 patients met the inclusion criteria. In the allocation stage, the samples were assigned to one of two intervention groups (30 individuals) or control (30 individuals) using the random allocation method. At this stage and before starting the intervention, five individuals from each group withdrew from the study; therefore, the study was completed with 25 individuals in each group. During the intervention and follow-up, no participant was excluded. Finally, data analysis was performed on 25 participants in each group (Figure 2).

The patients' mean age was 56.4, with a standard deviation of 13.2 years. The minimum and the maximum ages were 26 and 78 years, respectively. The mean duration of kidney disease was 9.1 years with a standard deviation of 7.6 years. The number of dialysis sessions per week was 3. No patient experienced shivering. The type of hemodialysis solution in all patients was a concentrated solution. No patient had a history of allergic reactions to hemodialysis solution.

Examining the homogeneity of participants' demographic characteristics showed that the demographic variables (including gender, occupation, place of residence, marital status, education, and body mass index) were identical in the two groups, and there was no statistically significant difference ($p < 0.05$) (Table 1). It should be

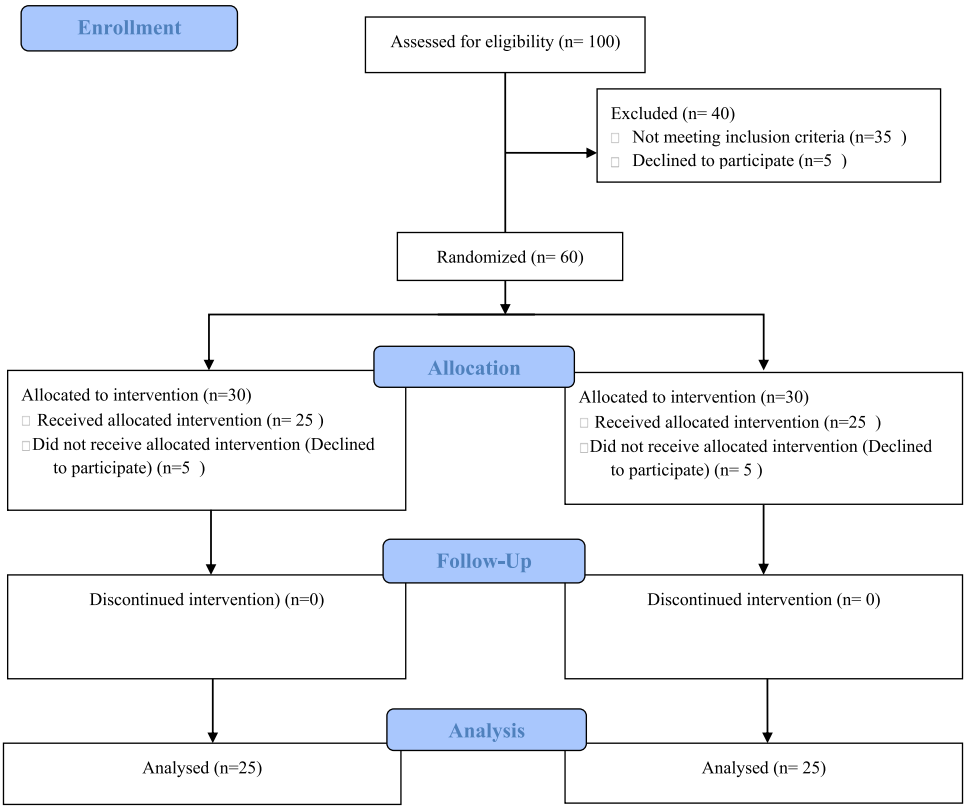

FIGURE 2 CONSORT flow diagram.

TABLE 1 Frequency distribution and homogeneity of study subjects based on demographic variables.

Variable/group		Intervention Frequency (percentage)	Control Frequency (percentage)	Test statistics	*p* Value
Gender	Male	13 (43.3)	17 (56.7)	1.33	0.248
	Female	12 (60)	8 (40)		
Marital status	Single	3 (50)	3 (50)	0.00001	0.999
	Married	22 (50)	22 (50)		
Occupation	Housewife	15 (45.5)	18 (54.5)	0.802	0.370
	Other	10 (58.8)	7 (41.2)		
Address	City	18 (51.4)	17 (48.6)	0.095	0.758
	Village	7 (46.7)	8 (53.3)		
Level of education	Diploma and below	17 (47.2)	19 (52.8)	0.397	0.529
	Higher	8 (57.1)	6 (42.9)		
Body mass index	<25	19 (52.8)	17 (47.2)	0.397	0.529
	>25	6 (42.9)	8 (57.1)		

noted that there was no statistically significant difference between the intervention (56.7 ± 14.3) and the control groups (56.2 ± 12.3) in terms of age ($p < 0.05$). Moreover, no statistically significant difference was found between the intervention and control groups regarding the history of kidney transplantation, history of underlying disease, hemodialysis after eating, access to vessels, type of membrane, history of kidney disease, history of hemodialysis, amount of sodium, potassium, creatinine, urea nitrogen, systolic and diastolic blood pressure, and body temperature ($p < 0.05$) (Tables 2 and 3).

Data analysis related to the mean score of nausea severity in patients in the intervention group before, during, and after hemodialysis was 0.72, 0.1, and 0.56, respectively. The variance analysis of

TABLE 2 Frequency distribution and homogeneity of study subjects based on clinical variables.

Variable/group		Intervention Frequency (percentage)	Control Frequency (percentage)	Statistical test	*p* Value
Hemodialysis shift	Morning	10 (50)	10 (50)	0.240	0.624
	Noon	7 (50)	7 (50)		
	Evening	1 (16.7)	5 (83.3)		
	Combined	7 (70)	3 (30)		
Kidney transplant history	Yes	5 (45.5)	6 (54.5)	0.117	0.733
	No	20 (51.3)	19 (48.7)		
Performing hemodialysis immediately after eating food	Yes	11 (57.8)	8 (42.1)	0.764	0.382
	No	14 (45.2)	17 (54.8)		
Position during hemodialysis	Sitting	3 (50)	3 (50)	0.0001	0.999
	Half sitting	10 (50)	10 (50)		
	Supine	12 (50)	12 (50)		
Type of dialysis machine	Gambro	0 (0)	2 (100)	5.38	0.146
	Nipro	2 (28.6)	5 (71.4)		
	Fresenius	6 (42.9)	8 (57.1)		
	Bbraun	17 (63)	10 (37)		
Vascular access	Indwelling catheter	15 (68.1)	7 (31.9)	92/2	0.087
	Fistula	12 (42.9)	16 (57.1)		
The type of membrane	High flux	18 (60)	12 (40)	0.951	0.622
	Low flux	2 (40)	3 (60)		
	Combined	11 (55)	9 (45)		

TABLE 3 Descriptive statistics and homogeneity test of clinical variables among the study participants.

Variables/groups	Intervention Mean ± standard deviation	Control Mean ± standard deviation	*T*	*p* Value
History of kidney disease (years)	4.7 ± 3.4	10.2 ± 7.1	0.109	0.914
History of hemodialysis (year and month)	4.2 ± 4.6	8.1 ± 8.2	−0.863	0.392
Blood sodium	139.4 ± 3.02	139.4 ± 3.5	0.043	0.966
Blood potassium	4.8 ± 0.5	4.8 ± 0.4	0.285	0.777
Blood creatinine	9.2 ± 2.2	8.9 ± 1.9	−0.543	1.589
Blood urea nitrogen	79.6 ± 41.4	62.08 ± 39.8	−1/52	0.134
Systolic blood pressure before hemodialysis	151.3 ± 24.3	138 ± 25.4	−1/88	0.065
Diastolic blood pressure before hemodialysis	94.2 ± 13.6	89.8 ± 14.9	−1/09	0.279
Body temperature (°C)	36.8 ± 0.48	36.9 ± 0.44	0.889	0.379

repeated measures showed that the trend of changes in this group's mean score of nausea severity was significant ($p < 0.05$). Furthermore, the findings of this test showed that in the control group, the mean score of nausea severity before, during, and after hemodialysis was 1.6, 1.2, and 1.08, respectively, and there was a significant difference in the changing trend of the mean score of nausea severity (05.05). The most significant decrease in the severity of nausea was observed in the intervention group. Moreover, the mean score of

nausea severity before hemodialysis was 1.6 in the intervention and 1.6 in the control groups. The independent t-test showed no statistically significant difference between the two groups' mean score of nausea severity before hemodialysis ($p < 0.05$). According to the results of this test, the mean score of nausea severity during hemodialysis in the intervention and control groups were 0.72 and 1.2, respectively, and no statistically significant difference was found between the two groups ($p < 0.05$). Besides, the results of this test after intervention showed that the mean score of nausea severity in the intervention and the control groups were 0.56 and 1.8, respectively, indicating no statistically significant difference (Table 4).

The results of the two-way variance analysis of repeated measures showed that the mean score of nausea severity decreased significantly over time ($p < 0.05$); however, no significant difference was observed between the groups ($p < 0.05$). Based on the findings, the effect of evaluation time (before, during, and after hemodialysis) was significant in the intervention and control groups. In other words, regardless of the group type, the mean score of nausea severity decreased in the intervention and control groups as more time passed from hemodialysis with cold solution (evaluation time). However, in the intervention group, the trend of reduction in the severity of nausea was more significant. Therefore, there was no significant difference in the effect of treatment groups, which implies that regardless of the days of evaluation, no significant difference was observed between the mean score of nausea severity based on the patients' condition after hemodialysis. Although the reduction in the severity of nausea was evident in the intervention group, this difference was not statistically significant (Table 5). As shown in Figure 3, the mean score of nausea severity in the intervention and control groups has significantly decreased.

The present study caused no harm or unintended effects in the intervention and control groups.

4 | DISCUSSION

The findings of the present study showed that the reduction in the severity of nausea in the intervention group was greater than in the control group after the intervention with the cold dialysate; however, there was no statistically significant difference in the mean score of nausea severity after the intervention in the two groups. The findings of the present study were inconsistent with the studies by Borzou et al. and Shahgholian et al.[21,29,30]

The study by Borzou et al.[21] conducted to investigate the effect of hemodialysis with a cold dialysate on hypotension during hemodialysis showed that hypotension symptoms such as nausea and vomiting occurred less frequently.[21] The results of this study are not in line with the results of our study. Borzou et al.'s study had some shortcomings, such as not mentioning the use of nausea and vomiting medications, which could have influenced the results, whereas, in the present study, patients undergoing treatment with nausea and vomiting medications were not included.[21] On the other hand, Xu et al.[31] used a cold hemodialysis solution to prevent hypotension during hemodialysis. This study showed that at low temperatures, patients experienced fewer hypotension complications, such as nausea and vomiting.[31] However, they had not used a specific and standard tool to measure nausea and vomiting. In the present study, the rate of nausea was measured using a VAS.

Shahqalian et al.[29] conducted a study investigating the effect of ultrafiltration and sodium profiles 3 and cool dialysate on hypotension during hemodialysis and associated symptoms. The study was carried out in three stages. In each stage, eligible subjects received dialysis based on one of the methods: sodium profile 3 and ultrafiltration profile 3, cool dialysate, or the combination of both methods. The findings showed that the incidence of hypotension and

TABLE 5 Changes in the severity of nausea before, during, and after hemodialysis in intervention and control groups.

Time/group				Repeated measure test, Green House-Geiser	
	Before	During	After	intragroup	intergroup
Nausea severity	1.6 ± 2.6	0.72 ± 1.3	0.56 ± 0.9	$p = 0.001$ $F = 13.7$	$p = 0.509$ $F = 0.443$
	1.6 ± 2.3	1.2 ± 1.8	1.08 ± 1.6		
$p = 0.001$ $\chi 2 = 36.8$				Mauchly's test	

TABLE 4 The comparison of nausea severity in patients before, during, and after hemodialysis.

Variable/group		Intervention Mean ± standard deviation	Control Mean ± standard deviation	Statistical index
Severity of nausea	Before hemodialysis	1.6 ± 2.6	1.6 ± 2.3	p-value = 0.956 $t = -0.056$
	During hemodialysis	0.72 ± 1.3	1.2 ± 1.8	p-value = 0.256 $t = 1.12$
	After hemodialysis	0.56 ± 0.9	1.08 ± 1.6	p-value = 0.265 $t = 1.35$
Statistical index		p-value = 0.005 $F = 9.6$	p-value = 0.002 p-value = 0.5002	

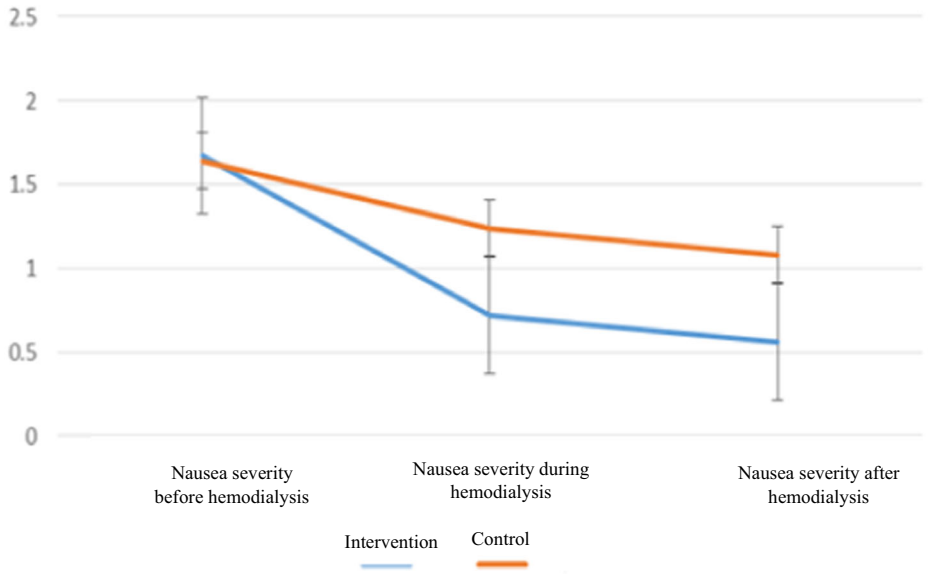

FIGURE 3 The diagram of changes in the mean severity of nausea before, during, and after hemodialysis in the intervention and control groups.

associated symptoms such as nausea and vomiting using the combination of sodium profile 3, ultrafiltration, and cool dialysate were less compared to each method alone[29,30,32]; however, their study had shortcomings, such as lack of a control group.

Among the studies in line with the present study, the study by Moattari et al.[22] conducted to investigate the effect of cool dialysate on hypotension during hemodialysis in patients with end-stage renal failure showed that during cold hemodialysis, all hypotension symptoms except for nausea, vomiting, and muscle cramps were significantly fewer than hemodialysis using the normal method.[22] The results of Moattari et al.'s study are in line with the results of our study. The use of cold hemodialysis to control hypotension during hemodialysis began in 1980. After years, researchers have realized that cold hemodialysis not only reduces the incidence of hypotension during hemodialysis but also has other beneficial effects on overall health and quality of life.[33]

The cooled hemodialysis fluid can transfer heat from the blood to the hemodialysis solution and prevent increased body temperature,[34] which can inhibit complications, such as nausea, vomiting, and itching during hemodialysis.

Hemodialysis patients, who are usually hypothermic, gain extra heat during hemodialysis. The increase in body temperature seems to be caused by increased sympathetic activity and severe contraction of peripheral vessels.[35,36] Parker et al. showed that cold hemodialysis reduced the stimulation of the sympathetic nervous system and improved hemodialysis patients' skin temperature.[37] An increase in body temperature often causes reflex vasodilation, an increased venous capacity, and a decreased cardiac output, all of which cause a drop in blood pressure during hemodialysis, the most common complication observed during the treatment.[38,39]

A slight reduction in the temperature of the hemodialysis solution helps reverse these changes by releasing more catecholamines, increasing arterial and central venous tonicity, venous return, and cardiac output.[40] The peripheral vascular resistance increases when a cold hemodialysis solution is used. In addition, cold hemodialysis improves the left ventricular contractility independent of preload and afterload, preventing blood pressure drop during hemodialysis.[41] Since nausea and vomiting during hemodialysis is one of the adverse effects of hypotension, it was expected that hemodialysis with a cooled dialysate could reduce the incidence of nausea in hemodialysis patients.

Regarding the degree of shivering in hemodialysis patients after cold hemodialysis, the findings showed that no patient experienced shivering. The study by Borzou et al.[21] conducted to investigate the effect of using a cold dialysate on the vital signs, comfort, and adequacy of dialysis in patients undergoing hemodialysis was consistent with the findings of the present study. Their study's results indicated that patients' comfort level was higher at 36°C temperature than at other temperatures, and most patients preferred to permanently receive hemodialysis at 36°C temperature. However, 73.3% of patients felt cold or shivering at a temperature of 35°C.[21] The temperature of 36°C as the selected temperature for the cold hemodialysis can be considered as the reason for the agreement of the present study results with the results of Borzou et al.'s study.

Other studies likewise showed that most patients undergoing hemodialysis with a cooled solution felt energetic and improved general health. Therefore, they managed to continue this method in the subsequent hemodialysis sessions.[41]

The studies by Ayoub et al. and Balan et al. were among the studies inconsistent with the present study regarding the occurrence of shivering in hemodialysis patients.

Ayoub et al.[42] conducted a clinical trial in New Zealand to investigate the effect of cooling the hemodialysis solution on the quality of hemodialysis and patients' perception of the treatment.

The samples included 10 patients divided into two groups of 5 that underwent hemodialysis in two groups for six sessions. Three sessions were performed at normal temperature (standard hemodialysis), and three sessions using a cold dialysate. The results indicated that 20% of the patients felt cold and shivered during cold hemodialysis,[42,43] which is not in line with the results of our study. The reason might be the difference in the temperature selected for the hemodialysis solution in the intervention group. In other words, in our study, 36°C was chosen as the temperature of the cold solution; however, in the study by Ayoub et al., a temperature of 35°C was used.

Bullen et al.[44] conducted a study to determine the effect of cold hemodialysis on hypotension during hemodialysis and the patients' perception of the treatment. The results showed that a large number of patients complained of feeling cold during hemodialysis,[44] which is inconsistent with the results of our study. The reason for this problem might be the difference in the temperature selected for the cold hemodialysis solution, as in their study, the cool dialysate temperature was half a degree lower than the patients' body temperature.

One of the limitations of the present study is the reliance on patients' self-reports of nausea severity. Due to the impossibility of tests and other diagnostic measures to determine the severity of nausea, the researchers relied on the patients' reports since controlling this limitation was beyond their ability. While conducting this study, in addition to achieving the intended goals and questions, the researcher encountered questions that necessitate broader research in this field. Therefore, the following two suggestions are presented for further studies:

1. Comparison of the effect of cold hemodialysis and other nonpharmacological methods on the rate of nausea in hemodialysis patients.
2. Comparison of the effect of cold hemodialysis on the rate of nausea at three temperatures: 35°C, 36°C, and 37°C.

5 | CONCLUSION

Although the results of the present study were not significant regarding the effect of cold hemodialysis on the rate of nausea in patients, according to the results, the reduction in the severity of nausea in the intervention group was greater compared to the control group.

Given the increasing prevalence of chronic renal failure and the number of patients receiving hemodialysis, as well as the disadvantages and inadequacies of interventions such as nausea and vomiting medications and normal saline serum infusion, it is hoped that this type of intervention will be considered a nonpharmacological treatment in managing complications during hemodialysis, nausea and vomiting in particular, by conducting further studies on the effect of lowering the temperature of hemodialysis solution on the rate of nausea and vomiting in patients undergoing hemodialysis.

5.1 | Implications of findings

1. Nursing education authorities and planners can use the findings of this study and similar studies to develop an educational program to help nurses and nursing students learn about non-pharmaceutical methods of controlling complications during hemodialysis using a cold dialysate. Moreover, further studies need to be conducted considering the importance of preventing adverse effects during hemodialysis.
2. By developing the necessary guidelines, nursing managers in hemodialysis wards can provide the opportunity to use this method for patients undergoing hemodialysis. Therefore, the findings of this study and similar studies can help nursing care providers increase the adequacy of hemodialysis and minimize complications during hemodialysis.

AUTHOR CONTRIBUTIONS

Yasem Arghide: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; writing—original draft; writing—review and editing. **Azam Faraji**: Conceptualization; investigation; methodology; validation; writing—review and editing. **Ali Akbar Vaisi Raygani**: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing—original draft; writing—review and editing. **Nader Salari**: Conceptualization; formal analysis; investigation; methodology; software; validation; writing—original draft; writing—review and editing. **Hamidreza Omrani**: Conceptualization; formal analysis; investigation; methodology; project administration; writing—original draft; writing—review and editing. **Mohammad Mehdi Mohammadi**: Conceptualization; formal analysis; investigation; methodology; project administration; supervision; writing—original draft; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data analyzed and materials used in this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study was ethically approved by the ethics committee of Kermanshah University of Medical Sciences (IR.KUMS.REC.1398.18).

The researcher obtained the written informed consent of each participant. Participants were assured that they had the right to withdraw from the study at any stage. All participants were informed about the study process and its objectives, and written informed consent was obtained from them.

TRANSPARENCY STATEMENT

The lead author Ali Akbar Vaisi Raygani affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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