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Effect of a dynamic positioning–assisted dialysis nursing model on dry weight attainment

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Abstract

Background:: Based on the concept of Hydrostatic Indifference Plane（HIP）investigate the hemodynamic effects of the combined Passive Leg Raising(PLR) and Tilt position on maintenance hemodialysis (MHD) patients, with a focus on preventing intradialytic hypotension (IDH) and hypertension during dialysis blood reinfusion, thereby improving the achievement rate of Dry Weight (DW).

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Data Availability Statement

All data generated or analyzed during this study are included in this published article (and its supplementary information files).For further inquiries, please contact the corresponding author.

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Methods: 72 MHD patients were randomly divided into an observation group and a control group (36 each). Using the Fresenius 4008S dialyzer's relative blood volume (RBV) monitoring, the control group stopped ultrafiltration when the RBV curve dropped sharply, while the observation group maintained PLR. If the RBV curve rebounded, ultrafiltration was resumed with an extra 150–500 ml; if it plateaued, the current weight was set as provisional DW. Compare the overhydration (OH), total body water (TBW), extracellular water (ECW), intracellular water (ICW), as well as the systolic blood pressure （SBP）diastolic blood pressure（DBP）mean arterial pressure（MAP） at the start of dialysis, the end of ultrafiltration, and the end of dialysis blood reinfusion between the two groups.Over 3 months, indicators like IDH incidence, ultrafiltration adjustments, Overhydration(OH), TBW、ECW、ICW and DW compliance rate were compared.

Results: Both groups of patients underwent 1,296 dialysis sessions. The observation group had significantly fewer cases of IDH than the control group (288 vs. 432 sessions), with a higher ultrafiltration volume (3.1±0.52 vs. 2.8±0.34 L). Marked improvements were observed in OH, TBW, ECW and ICW in the observation group. At the end of ultrafiltration, the SBP , DBP and MAP in the observation group were all higher than those in the control group; whereas at the end of blood reinfusion, the SBP, DBP and MAP in the observation group were lower than those in the control group. Additionally, the observation group achieved a notably higher DW compliance rate (94.44% vs. 36.11%, all $P<0.01$).

Conclusion: Dynamic positioning adjusts fluid distribution, effectively prevents IDH, ensures ultrafiltration completion, and boosts DW compliance.

Introduction

The imbalance between ultrafiltration and reinfusion rates in maintenance hemodialysis (MHD) patients is considered a primary cause of intradialytic hypotension (IDH). However, whether discontinuation of ultrafiltration due to IDH is a major factor contributing to failure in achieving target Dry Weight(DW) remains unclear. During the dialysis reinfusion phase, the rapid reinfusion of a large volume of fluid over a short period will lead to transient hypervolemic load.Fluid overload is closely associated with adverse intradialytic events, as well as both short- and long-term cardiovascular complications(1) .The hydrostatic indifference plane (HIP) is a key physiological concept for explaining the effects of body position on the circulatory system. Its core definition is that there exists a reference plane within the body at which pressure is not influenced by gravitational hydrostatic forces. Under normal physiological conditions, the HIP is located approximately at the level of the right atrium (near the thoracic inlet). From a fluid mechanics perspective, changes in body position cause gravity-driven redistribution of blood within the body, leading to reconstruction of blood volume distribution(2). Based on the concept of HIP, the “Dynamic Positioning–Assisted Dialysis Model” proposed by Ao Hua et al(3), incorporates dynamic combinations of sitting, tilt, supine, and passive leg raising (PLR) positions. This model allows continuous, flexible transitions between postures to facilitate endogenous fluid redistribution, thereby stabilizing hemodynamic parameters during hemodialysis (HD). The present study aims to further evaluate the application of this model in reducing the incidence of IDH and improving DW attainment, thereby exploring its clinical significance in HD management.

Methods

Study Design

A total of 72 patients undergoing maintenance hemodialysis (MHD) in the Department of Nephrology from June 2022 to August 2025 were enrolled, including 37 males and 35 females. Patients were prospectively randomized into two groups of 36 each, with a mean age of 58.14 ± 8.03 years.

Inclusion criteria

(1) MHD duration of more than 6 months; (2) Independent in daily activities and receiving regular HD sessions three times per week.

Exclusion criteria

(1) Patients with fractures, spinal deformities, or impaired self-care ability; (2) History of severe hepatic, pulmonary, or neurological diseases; (3) Body mass index (BMI) < 18.5 kg/m² (underweight).

All patients underwent cardiac function assessment, chest CT examination, and collection of HD-related parameters, including pre- and post-dialysis body weight and ultrafiltration volume. Additional baseline characteristics are presented (Table 1). The study was approved by the Ethics Committee of China Three Gorges University, and written informed consent was obtained from all participants.

Table 1
Comparison of basic conditions between observation group and control group

age[($\bar{x}$ ± s), Year]	**Observation group(n = 36)**	**Control group (n = 36)**	**χ^2/t**	***P***
	58.32 ± 8.04	**57.96 ± 8.12**	**0.278**	**0.781**
Transit period[($\bar{x}$ ± s), Month]	41.66 ± 10.65	40.69 ± 10.68	0.386	0.700
hypertension [n(%)]	28(77.78)	26(72.22)	0.296	0.586
diabetes[n(%)]	29(80.56)	28(77.78)	0.074	0.786
Hyperuricemia [n(%)]	20(55.56)	22(61.11)	0.247	0.619
Other [n(%)]	7(19.44)	8(22.22)	0.0740	0.786
BMI[($\bar{x}$ ± s), kg/m^2)]	22.22 ± 1.22	22.25 ± 1.42	0.189	0.851
Body Weight(kg)	66.2 ± 4.9	65.8 ± 5.2	0.312	0.756
BUN[($\bar{x}$ ± s), mmol/L]	18.38 ± 7.19	17.50 ± 7.34	0.760	0.448
Hb[($\bar{x}$ ± s), g/L]	108.78 ± 7.51	109.54 ± 7.60	0.625	0.533
Alb[($\bar{x}$ ± s), g/L]	34.97 ± 2.57	35. 27 ± 2.97	0.664	0.508

The comparison between the two groups was $p < 0.05$

1.2 Instrument and method

Dialysis Setting

All patients were dialyzed for 4 hours, a selected ultrafiltration-to-weight ratio (V_{uf}/ m_d) of 0.04 is the critical threshold for the occurrence of IDH When it exceeds 0.06–0.07, it will lead to insufficient effective blood volume, which in turn directly increases the risk of IDH. This is particularly applicable to elderly patients and diabetic patients, and can serve as a potential early warning indicator for preventing intradialytic hypotension. (4)International Society of Peritoneal Dialysis (ISPD) guideline was followed Dialysis Prescription.

BLOOD VOLUME MONITORING(BVM)

The application of BVM was first realized by the CRIT-LINE® technology developed by Fresenius Medical Care. This technology enables non-invasive, real-time measurement of hematocrit changes during hemodialysis, and the calculated RBV has been integrated into hemodialysis device platforms.During the ultrafiltration process, a stable blood volume monitoring curve ("flat BVM curve") is referred to as "BVM wet" (Fig. 1), defined as a RBV decrease of < 5% throughout the ultrafiltration period. This indicates that the plasma refilling rate is equal to or higher than the ultrafiltration rate, suggesting potential room for further increasing the ultrafiltration target and adjusting the patient's Dry Weight. RBV decrease of > 5% is termed "BVM dry". In this case, the ultrafiltration device should be turned off, and RBV should be remeasured after 10 minutes. If RBV increases by ≥ 1.5% due to vascular refilling, it indicates excessive fluid refilling from the extravascular space, suggesting volume overload in the patient, and moderate ultrafiltration can be performed. Otherwise, ultrafiltration should be terminated.(5) The control group was operated in accordance with this procedure, while the observation group was placed in the passive leg-raising position at this time. If RBV increased by ≥ 1.5%, ultrafiltration was increased and the curve changes were continuously observed; if the curve showed a downward trend, ultrafiltration was terminated.

The curve of segment AB is referred to as "BVM wet" (Fig. 1), which is defined as RBV decrease of < 5% throughout the ultrafiltration period.The curve of segment BC, which indicates a RBV decrease of > 5%, is termed "BVM dry".The curve of segment CD indicates that RBV increases by ≥

1.5% under the intervention of PLR position.

Definitions

BP was collected before and after each dialysis session at 30-minute intervals, during the session. IDH : a decrease in systolic blood pressure (SBP) ≥ 20 mmHg (or a decrease in MAP ≥ 10 mmHg) during HD with or without symptoms of hypotension, namely,abdominal discomfort, nausea and vomitus, syncope, etc. or any condition in need of medical intervention(6). identifies patient-visits with elevated blood pressure after Blood Reinfusion in the late stage of hemodialysis (defined as a blood pressure of ≥ 140/90 mmHg and a systolic blood pressure increase of ≥ 20 mmHg).

The dynamic position model consists of four basic body positions

Supine position: The bed surface is fully horizontal, and the patient's body is completely in contact with the bed. This serves as the basic position for hemodialysis;Tilted position: The upper body is elevated with moderate support for the lower limbs. As a transitional position between the supine and upright positions, it is suitable for patients with heart failure or during the dialysis termination phase;Upright Sitting position: The upper body is held in an upright posture with the lower limbs hanging naturally. It is applicable for patients with heart failure or during the dialysis termination phase;PLR: On the basis of the supine position, the leg rest and thigh rest are elevated in a collinear manner to passively lift the patient's legs, which is used to alleviate hypotension.

a. Supine position: The footrest AB, sliding arm BC, leg rest BD, thigh rest DE, bed board EF and backrest FG are all in a horizontal state. The backrest FG is supported by the stay bar MN. At this time, the bed board EF is at the limit position closest to the backrest FG, and the end C of the sliding arm BC is located at position H.

b. Transition from supine position to tilted position: On the basis of the supine position, the bed board EF slides toward the end E. The backrest FG is propped up by the stay bar MN under the action of traction force. With the end C of the sliding arm BC fixed, the leg rest BD and thigh rest DE will fold upward along the end D. The armrest EL is lifted synchronously with the backrest FG. The conversion between these two positions is reversible.

c. Transition from tilted position to sitting position: On the basis of the tilted position, the bed board EF remains fixed. The end C of the sliding arm BC slides along the horizontal track J-H-K-I toward the side of I to the position K. The leg rest BD and thigh rest DE will fold downward to the underside of the bed board EF due to the movement of the end C. The conversion between these two positions is reversible.

d. Transition from supine position to PLR: On the basis of the supine position, the bed board EF remains fixed. The end C of the sliding arm BC slides along the horizontal track J-H-K-I toward the side of J to the limit position J. The half-open hinge between the leg rest BD and thigh rest DE makes them collinear, and the footrest AB is lifted upward. The conversion between these two positions is reversible.

Due to the poor sensitivity of intermittent blood pressure monitoring, the RBV slope was adopted as the trigger point for positional change. The postural sequence is illustrated in steps and of Fig. 1.

During hemodialysis, maintaining the passive leg raising (PLR) position until the blood reinfusion phase, and then gradually shifting to tilting or even sitting position in synchrony with blood return—depending on blood pressure and other hemodynamic parameters (step)—helps optimize fluid management. The involvement of vascular refilling and partial replenishment from the returning blood volume prevents intradialytic hypotension during ultrafiltration, thereby allowing greater fluid removal and improving achievement of dry weight (DW).,

All patients were treated with Fresenius Dialysis Machine 4008S (Fresenius Medical Care, St. Wendel, Germany). Conventional hemodialysis (HD) was performed using a Fresenius F6 low-flux polysulfone hollow fiber dialyzer. Low-molecular-weight heparin was selected as the anticoagulant. The composition of the dialysate was as follows: calcium concentration of 1.25 mmol/L, sodium concentration of 135–140 mmol/L, and magnesium concentration of 0.5 mmol/L. The dialysate flow rate was 500 mL/min, and the dialysate temperature was maintained at 36.0–36.5°C. The European Best Practice Guidelines (EBPG) recommend an equilibrated $Kt/V \geq 1.2$ as the minimum adequate dialysis dose. In Kt/V, $*K*$ represents the urea clearance of the dialyzer, $*t*$ the duration of a single treatment, and $*V*$ the volume of urea distribution. A value of 1.2 indicates that a volume of plasma equivalent to 1.2 times the urea distribution volume is cleared during a single dialysis session, which is sufficient to largely correct the accumulation of small-molecule uremic toxins.

The ultrafiltration device was turned off when the relative blood volume reduction amplitude exceeded 5%.If the ultrafiltration volume/body weight ratio was ≥ 0.04, ultrafiltration was discontinued.

$V_{uf} / m_d \geq 0.04$ (1)

Wherein: : V_{uf} = ultrafiltration volume (L); m_d = dry weight (kg). Clinical significance: Formula (1) serves as the risk warning threshold for intradialytic hypotension (IDH) (ultrafiltration shall be discontinued when the threshold is reached).

If the ultrafiltration volume/body weight ratio was < 0.04 and the relative blood volume increased by ≥ 1.5% after 10 minutes, ultrafiltration was resumed.

$V_{uf} / m_d < 0.04$ (2)

Clinical significance: When Formula (2) is satisfied and the relative blood volume (RBV) increases by ≥ 1.5%, ultrafiltration may be resumed.

In case of intradialytic hypotension (IDH) occurrence, ultrafiltration is discontinued. If IDH persists after 30 minutes, temporary adjustment is made by reinfusing 100–150 ml of saline.Observation group: When the RBV curve shows a steep decline (When the relative blood volume reduction amplitude exceeds 5%), or IDH occurs,passive leg raising (PLR) is maintained, followed by gradual transition to the sitting position during the blood return phase. During the ultrafiltration phase, if the RBV curve exhibits a rebound following a decline(RBV increases by ≥ 1.5%), the ultrafiltration volume may be appropriately increased by 150–500 ml. A stable and gradual curve suggests that the patient's temporary DW has been achieved for the current dialysis session, with further adjustments to be made in subsequent sessions. Volume load and cardiac function are evaluated before and after three months of positional interventions.

DW、TBW、and ECW

NICaS Hemodynamic Status and Bioelectrical Impedance Analysis (BIA), (NI Medical, Petah-Tikva, Israel;NICaS CS)This study adopted thoracic bioimpedance, and there is literature reporting that thoracic bioimpedance is more suitable for hemodialysis patients (7). Bioelectrical impedance measurements were performed before dialysis and half an hour after the end of dialysis.DW is defined as the body weight at which excess fluid is removed without symptoms of dehydration, and it can be estimated more precisely using the OH value(8) .BIA measurements included total body water (TBW), extracellular water (ECW), intracellular water (ICW), the ECW/TBW ratio, the ECW/ICW ratio, stroke volume (SV), and total body water (TBW) levels. Chamney Slope Method(9), This method is based on the assumption that, with progressive fluid removal during dialysis, patients gradually approach the normal volume status of healthy individuals. Dry weight is estimated at the point where the percentage of extracellular water (ECW%) intersects with the normal slope of ECW to total body water (TBW). The formula is:

$$\mathrm{m_d} = \frac{m_{\mathrm{pre}} - V_{\mathrm{ec,m}}}{1 - r_{\mathrm{ec,b}}^{\mathrm{ref}}}$$

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m_{d} = dry weight (kg); m_{pre}= pre-dialysis/pre-ultrafiltration weight (kg); Vec,m = extracellular water mass measured by bioelectrical impedance analysis (BIA) (kg); $r_{\mathrm{ec,b}}^{\mathrm{ref}}$= reference median of extracellular water/total body water (ECW/TBW) ratio in healthy population with the same body mass index (BMI).

Definition of Overhydration (OH)(10): Overhydration can be expressed either as an absolute value (in liters) or as a relative parameter. The relative parameter reflects the excess proportion of extracellular water. When the percentage of extracellular water excess is ≥ 15%, dialysis patients are considered overhydrated. The calculation is as follows:

$$\omega_{\mathrm{oh}} = \frac{V_{\mathrm{oh}}}{V_{\mathrm{ec}}} \times 100\%$$

4

ωoh= overhydration percentage (%);Voh= absolute overhydration volume (L);Vec = extracellular water volume (L).

Statistical Methods

Statistical analyses were performed using SPSS version 17.0. For quantitative variables, the Kolmogorov–Smirnov test was used to assess normality. Data conforming to a normal distribution were expressed as mean ± standard deviation ($\bar{x}$±s). Paired t-tests were applied for postural intervention comparisons of normally distributed data, while non-parametric tests were used for data not meeting normality assumptions. Categorical variables were analyzed using the χ^2 test. A two-sided $P < 0.05$ was considered statistically significant.

Results

The incidence of IDH

During the 3-month, both the observation group and the control group have 1296 patient-visits(PVs), the incidence of intradialytic hypotension (IDH) in the control and observation groups in ultrafiltration phase was 432 PVs(33.33%) 288 PVs(22.22%). (Table 2.) All episodes of IDH occurred after changes in RBV slope, and the time points of RBV slope changes in the two groups 3.21 ± 0.45 h vs 3.19 ± 0.48 h, P>0.05). Table 3.

The association between BP changes

With position intervention, the blood pressure of the observation group was higher than that of the control group at the end of ultrafiltration, while it was lower than that of the control group at the end of blood reinfusion (Table 2). Statistical analyses revealed that the ultrafiltration phase decreasing amplitude of SBP was positively correlated with ΔBV ($P < 0.05$)ultrafiltration volume ($P < 0.05$)and V_{uf} / m_d ($P < 0.05$), With the intervention of PLR, the decreasing amplitude of SBP decreased significantly ($P < 0.05$), During the blood reinfusion phase, the amplitude of SBP elevation decreased significantly with the intervention of the Tilted Position. ($P < 0.05$)(Table 3.)

Relationship Between Ultrafiltration and DW, ICW, ECW under Posture Intervention

The actual ultrafiltration prescription ratio of ultrafiltration volume to body weight (V_{uf} / m_d) in the observation group and the control group was5.10 ± 0.32% vs 4.25 ± 0.08%($P<0.05$), The temporarily adjusted ultrafiltration volumes were3.1 ± 0.52 L and 2.8 ± 0.34 L ($P < 0.01$), while ΔBV values were 5.47 ± 0.62% and 11.20 ± 0.60%, with fluctuations between 13.5% and 19.7% accompanied by a steep decline in the RBV curve. After three months, the overhydration (OH) values were 2.74 ± 1.50 vs. 1.02 ± 0.22, and the dry weight (DW) compliance rates reached 36.11% (13 Pvs) 94.44% (34 Pvs), both showing statistically significant differences ($P < 0.01$).

As shown, ICW, ECW, and TBW ,ECW/ICW ratios ,ECW/TBW ratios decreased compared with baseline. Significant reductions were observed in ECW, TBW, ECW/ICW, and ECW/TBW ratios ($P < 0.01$).(Table 4)

Table 2
The SBP DBP MAP and RBV before and after Blood Return were compared between the two groups

SBP [mmHg]		**Observation Group(n = 36)**	**Control Group(n = 36)**	***t***	***P***
	Initiation of hemodialysis	**142.24 ± 11.31**	**141.11 ± 11.34**	**0.423**	**0.673**
End of ultrafiltration	**123.62 ± 8.34***	**110.25 ± 7.96***	**6.959**	**0.000**	
After blood reinfusion	**128.24 ± 9.23****	**139.42 ± 8.34****	**5.395**	**0.000**	
DBP [mmHg]	Initiation of hemodialysis	82.53 ± 8.51	83.11 ± 7.58	0.305	0.761
	End of ultrafiltration	77.52 ± 4.54*	65.55 ± 8.53*	7.428	0.000
	After blood reinfusion	78.12 ± 4.56$^{\Delta}$	80.59 ± 4.24**	2.383	0.020
MAP [mmHg]	Initiation of hemodialysis	100.22 ± 9.54	101.50 ± 8.89	0.594	0.555
	End of ultrafiltration	91.53 ± 6.04*	78.63 ± 10.82*	6.249	0.000
	After blood reinfusion	92.90 ± 9.54$^{\Delta\Delta}$	98.52 ± 5.54**	3.057	0.003
RBV [%]	Initiation of hemodialysis	100	100	39.5379	0
	End of ultrafiltration	11.20 ± 0.60	5.47 ± 0.62	18.3430	0
	After blood reinfusion	1.23 ± 0.31	2.39 ± 0.22		

Note: Compared with the baseline at the start of dialysis, the SBP/DBP/MAP/RBV of both the observation group and the control group decreased significantly at the end of dialysis ultrafiltration $p < 0.05$*.When compared with the values at the end of ultrafiltration, the SBP of both groups as well as the DBP and MAP of the observation group showed significant differences at the end of blood reinfusion $p < 0.05$**. However, it was found that for the observation group after postural intervention, theDBP ($t = 0.728$, $p > 0.05^{\Delta}$) and MAP ($t = 0.728$, $p > 0.05^{\Delta\Delta}$), which indicated the difference after postural intervention.

Table 3
Comparison of IDH, blood pressure rises during return period, temporary ultrafiltration volume(PVs), ΔBV and DW compliance between the control group and the observation group during the 3-month

grouping	Total PVs	Asymptomatic IDH(PVs)	Blood pressure rises during return to blood(PVs)	ultrafiltration volume(□)	V_{uf} / m_d(%)	Ultrafiltration period ΔBV(%)	Blood return phaseΔBV(%)	DW compliance rate(%)	the time points of RBV decrease of > 5% (h)
control group	1296	432	392	2.8 ± 0.34	4.25 ± 0.08	5.47 ± 0.62	2.39 ± 0.22	36.11	3.21 ± 0.45
observation group	1296	288	22	3.1 ± 0.52	5.10 ± 0.32	11.20 ± 0.60	0.23 ± 0.31	94.44	3.19 ± 0.48
χ^2/t		22.58	344.47	2.6539	15.1927	4.534	7.698	12.115	1.0938
p		<0.05	<0.05	0.0098	0	<0.05	<0.05	<0.05	>0.05

Table 4
Comparison of BIA test indexes between control group and observation group after 3 months

time	n	OH(%)	ICW(L)	TBW(L)	ECW(L)	ECW/ICW ratio(%)	ECW/TBW ratio(%)	DW (kg)
control group	36	2.74 ± 1.50	24.14 ± 3.51	40.24 ± 0.88	18.32 ± 2.28	0.60 ± 0.29	0.49 ± 0.05	63.5 ± 4.8
observation group	36	1.02 ± 0.22	22.64 ± 1.30	36.57 ± 0.46	13.12 ± 4.85	0.45 ± 0.09	0.40 ± 0.02	64.9 ± 4.5
t		5.125	2.4029	5.647	5.511	5.343	16.32	2.478
p		<0.05	0.0189	<0.05	<0.05	<0.05	<0.05	0.015

Discussion

Excess fluid parameters defined by bioimpedance have a significant impact on mortality and cardiovascular events in dialysis patients and are often associated with heart failure. Volume overload exacerbates cardiac dysfunction(11) .

Postural changes in endogenous fluid distribution have been recognized in clinical practice. Systolic blood pressure is typically 2–3 mmHg higher in the supine position than in the sitting position. Physiologically, gravitational effects and increased muscle tone in the sitting posture impose additional workload on the cardiovascular system, which may account, at least in part, for the blood pressure differences observed between the two positions(12). Such as using passive leg raising (PLR) for volume resuscitation (lying flat with legs raised at 45°, which increases venous return by 150–300 mL) to enhance left ventricular filling(13). Erdem E.(14) proposed PLR positioning for intradialytic hypotension (IDH) It was also found that stopping ultrafiltration during PLR did not result in a higher increase in blood pressure, and the blood pressure was more stable.

The inclined position during the hemodialysis blood reinfusion phase is an innovative technique, which is combined with the passive leg-raising position applied in the ultrafiltration phase. Ao Hua(3) introduced the “Dynamic Positioning-Assisted Dialysis Model.” In hemodialysis (HD), PLR can be dynamically combined with supine, Tilting and sitting positions. This postural adjustment helps stabilizing hemodynamics, preventing hypotension during ultrafiltration and hypertension during blood return. During dialysis, ultrafiltration reduces blood volume, thereby diminishing the pressure-regulating capacity of the HIP, resulting in insufficient venous return and a sudden drop in arterial pressure. In contrast, passive leg raising (PLR) elevates the lower limbs above the HIP (at the level of the right atrium), allowing gravity to promote the return of blood from the lower extremities toward the HIP, increasing cardiac preload and thereby maintaining arterial pressure stability and reducing the occurrence of intradialytic hypotension (IDH). In the present document, the incidence of IDH in the observation group was only 0.31%, markedly lower than the 8.64% observed in the control group.During the blood return phase, blood volume increases abruptly. If the patient remains in the supine position, vascular pressure above the HIP rises sharply, predisposing to hypertension. In contrast, a tilted or sitting position places the upper body farther from the HIP, allowing gravity to offset part of the pressure increase caused by blood return, thereby reducing the peak arterial pressure. Accordingly, at the end of the blood return phase, both systolic and diastolic blood pressures (SBP and DBP) were lower in the observation group than in the control group.

During dialysis, patients experience marked fluctuations in blood volume. In the late ultrafiltration phase, IDH frequently occurs, Following PLR maneuvers, the relative blood volume (RBV) curve showed a slight rebound ($P < 0.05$), It can ensure an increase in ultrafiltration volume, and with the increased ultrafiltration volume, the blood pressure at the end of ultrafiltration is higher than that of the observation group. ($P < 0.05$), In this study,. with a temporary increase in ultrafiltration, while IDH incidence significantly decreased compared to pre-intervention levels, This finding

confirmed the contribution of lower-limb venous return. It was found in this study that the change in the slope of RBV curve generally occurs at approximately 3.5 hours, indicating that ultrafiltration leads to a decrease in blood volume and blood pressure. IDH generally occurs after the change in the slope of the RBV curve, which suggests that monitoring the slope of the RBV curve is more sensitive than clinical observation for the detection of IDH. recommended PLR positioning for IDH without symptoms, but noted that the threshold for symptomatic IDH varies among patients (15).. During the blood return phase (2–3 minutes), blood volume increases by 250–300 ml, or more, which adds to cardiac load. PLR during the ultrafiltration phase creates a buffer space for the volume load of blood reinfusion. When blood reinfusion is performed, synchronously shifting the patient's position to the inclined position provides a buffer for the volume of reinfused blood, which prevents a rapid increase in the effective circulating blood volume of the heart within a short period. In this study, it was found that for the observation group after postural intervention, the DBP ($t = 0.728$, $p > 0.05^{\Delta}$) and MAP ($t = 0.728$, $p > 0.05^{\Delta\Delta}$) demonstrated the differences induced by postural intervention, there were also significant differences in the data comparison between the two groups.The "Dynamic Positioning-Assisted Dialysis Model" adjusts PLR based on changes in the RBV curve slope(3). Postural change reduces venous return to the heart due to gravitational pooling in the lower extremities, thereby minimizing the impact of the dialysis blood return volume on cardiac function. Clinical studies examining the relationship between body position and internal jugular vein pressure have demonstrated that(16), in the supine position, the correlation coefficient between internal jugular vein collapsibility and the noninvasive clinical standard of jugular venous pulsation height is $r^2 = 0.89$, with a mean absolute difference of 0.23 mmHg. When participants were tilted by 16 degrees, internal jugular vein pressure decreased, whereas it increased during the Valsalva maneuver. This stage effectively reallocates a portion of the blood return volume to compensate in advance for the ultrafiltrated volume, thereby preventing a reduction in ultrafiltration caused by blood return, which could otherwise lead to OH and failure to achieve DW. In the observation group, both the incidence of blood pressure elevations and ΔBV during the blood return phase were significantly reduced, indicating that postural intervention attenuated volume fluctuations and slowed the upward slope of the RBV curve.

Furthermore, Yu Haiping and colleagues compared supine, tilting, and sitting positions, and found that with increasingly upright posture, central venous pressure—reflecting venous return—showed a declining trend. These findings suggest that combining the leg-raising and sitting positions can effectively reduce venous return, prevent blood pressure elevation and volume overload during the blood return phase, thereby lowering the risk of cardiovascular events, while simultaneously facilitating greater fluid removal during ultrafiltration to achieve target DW.

Post-intervention results demonstrated decreases in intracellular water (ICW), total body water (TBW), and extracellular water (ECW), with ECW showing statistically greater changes than ICW ($P < 0.001$). This indicates that overhydration (OH) is primarily characterized by expansion of extracellular fluid. Regarding the relative contributions of ECW and ICW to OH, prior studies suggest that ECW serves as the major reservoir, with its expansion directly increasing vascular volume. Each additional liter of ECW raises the risk of cardiovascular events by 15%(17).

Limitations of This Study

A limitation of the present study is the absence of mechanical equipment and software support. The burden of care on healthcare providers and family members remains considerable. We aim to develop a software system capable of detecting trigger points for positional changes, allowing seamless transitions among leg-raising, supine, tilting, and sitting positions via nursing bed control. In addition, the small sample size highlights the need for further validation in large-scale, multicenter studies.

Conclusion

The dynamic positioning dialysis assistance system can improve patient comfort and treatment compliance, facilitate the completion of prescribed dialysis, and help achieve target dry weight while supporting cardiac function. Further research may contribute to advancing dialysis care.

Declarations

Author Contribution

F.H.wrote the main manuscript text . H prepared figures 1 and N.L. prepared figures 2,3 . All authors reviewed the manuscript.

Data Availability

All data generated or analyzed during this study are included in this published article (and its supplementary information files).For further inquiries, please contact the corresponding author.

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Figures

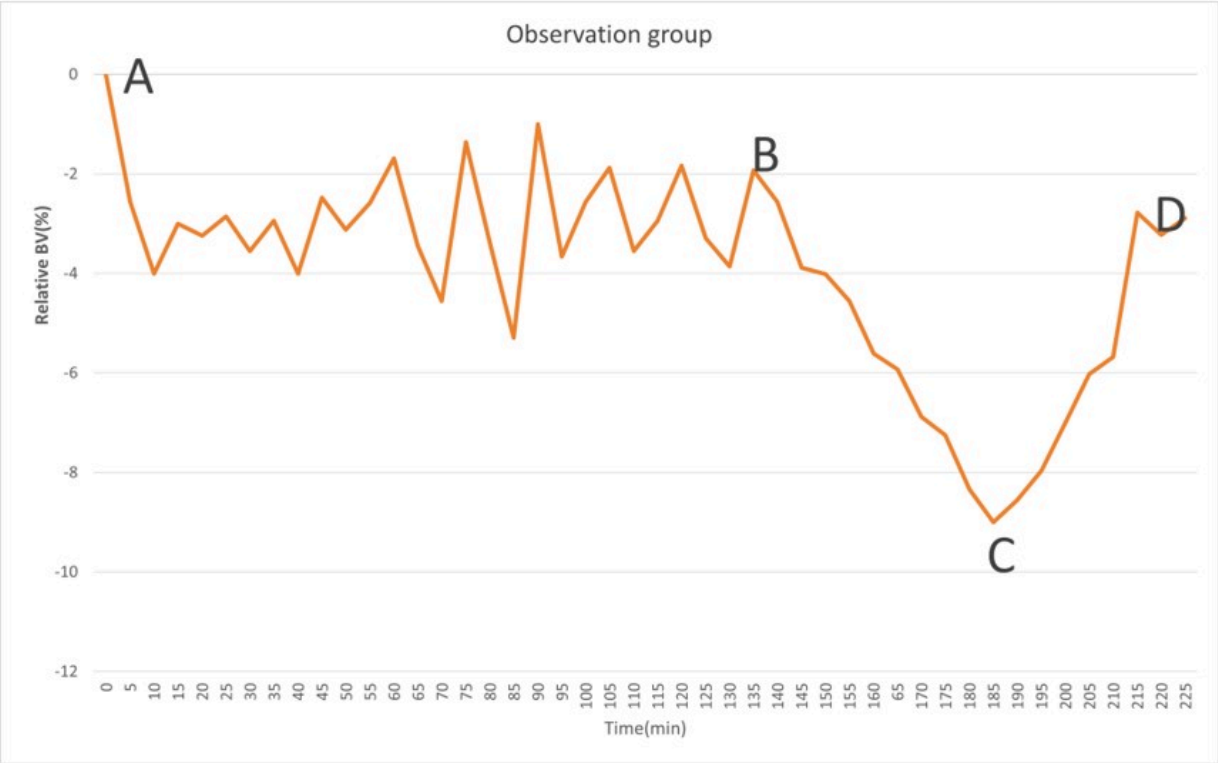


Figure 1

Changes in RBV Curve Under BVM

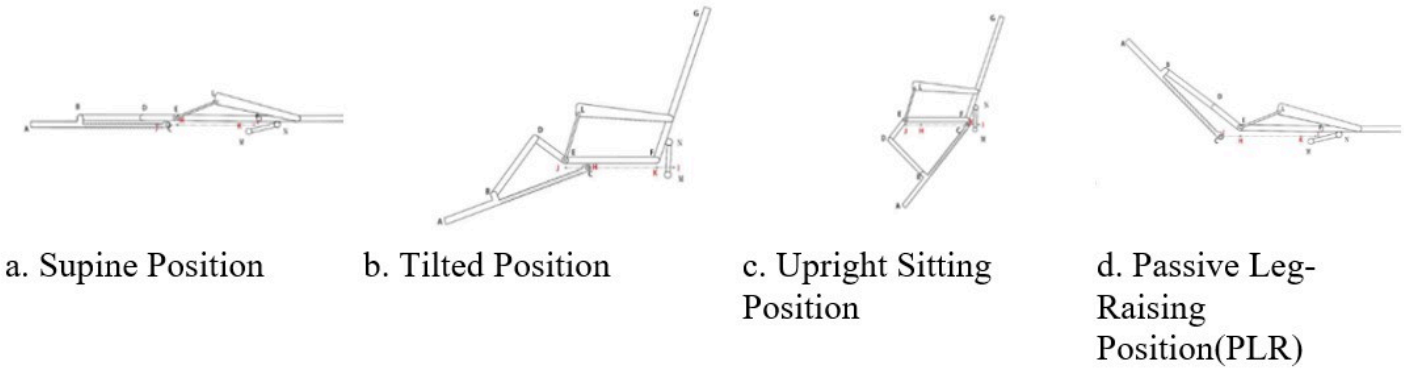


Figure 2

Schematic Illustration of the Operating Principle of the Dynamic Posture-Assisted Bed Surface



①Supine position when using the dialysis machine

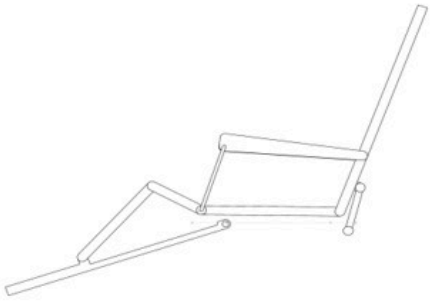


②When the RBV slope changes, the PLR position is maintained until the blood return period





③The position was synchronized with the return of blood from dialysis, and the PLR position was gradually changed to supine.



Tilting position

④with blood return from dialysis, gradually changing from supine to Tilting and finally sitting

Figure 3

Dynamic Posture-Assisted Dialysis System (Flow Chart of Routine Posture Intervention)