STUDY PROTOCOL

OFFICIAL TITLE:

Fluid Removal With a High Rate Ultrafiltration Protocol in Patients With Intravascular Congestion: the FILTRATE Trial

NCT NUMBER:

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Introduction

Cardio-renal syndrome encompasses a broad spectrum of disorders in which cardiac and renal dysfunction occur together, either simultaneously or as a continuum in which dysfunction in one organ triggers dysfunction in the other and vice versa. Regardless of the natural history of these conditions, all subphenotypes share the following characteristics: hemodynamic changes coupled with overactivation of neurohumoral pathways, fluid retention, an inability to generate adequate diuresis, and increased cardiac filling pressures [1,2].

Over the past 10 years, the pathophysiological understanding of cardio-renal-metabolic syndrome has evolved significantly, and with it, therapeutic efforts and the goal of improving the disease's prognosis. One of the strategies for decongestive therapy, when stepwise diuretic management is ineffective, is mechanical ultrafiltration, particularly in patients with advanced kidney disease [3,4,5,6]. With the advent of *POCUS (Point-of-Care* Ultras*ound)*, various studies have sought to estimate the degree of fluid overload and elevated filling pressures with the aim of reducing episodes of intradialytic hypotension, particularly in the context of acute kidney injury (AKI)[7] and in patients on hemodialysis as maintenance therapy[8] . The significance of intradialytic hypotension lies in its association with adverse cardiovascular outcomes, loss of residual renal function, and mortality[9] . The systematic review and meta-analysis, *"The Prevalence of Intradialytic Hypotension in Patients on Conventional Hemodialysis*," published in 2019 by the *American Journal of Nephrology*, identified a prevalence of <12% for intradialytic hypotension events using both the definition from the European Best Practices Guideline (EBPG) and a nadir <90 in conventional hemodialysis[10] . In a recent study, pulmonary ultrasound was used to guide ultrafiltration (UF) in patients with chronic kidney disease (CKD) of any etiology who were hemodynamically stable, without ventilatory support, and without a history of pulmonary disease or heart failure. All included patients underwent a 28-zone protocol prior to being connected to hemodialysis; and the rate of ultrafiltration in the intervention group was determined by the score based on the number of B-lines identified. The study found that patients with higher B-line scores had greater tolerance to ultrafiltration, with fewer episodes of intradialytic hypotension (6.7% in the intervention group vs. 37.7% in the control group); however, there was only an average difference of 300 mL more ultrafiltration in favor of the intervention group. In both groups, the ultrafiltration rate was maintained at <10 mL/kg/h, and there was no difference in the total number of sessions prior to discharge[7] . Another relevant study, the *Lung Water by Ultrasound-Guided Treatment in Hemodialysis Patients (LUST)* trial, analyzed whether the estimation of pulmonary congestion using ultrasound was useful for guiding ultrafiltration in patients with chronic kidney disease and high cardiovascular risk (history of AMI with or without ST-segment elevation, unstable angina, or any documented coronary syndrome; coronary

artery disease documented by prior angiography; or NYHA Class III–IV heart failure). The study consisted of two groups, an active arm and a control arm. In the active arm, pulmonary ultrasound was used to titrate the ultrafiltration rate. A total of 152 patients in the active arm and 155 in the control arm were analyzed, revealing a higher rate of pulmonary decongestion (78%) compared with the control group (56%), with an acceptable safety profile; however, there was no difference in the composite of major cardiovascular outcomes between the two groups (HR 0.88, 95% CI 0.63–1.24). A post hoc analysis identified a reduced risk in the treatment arm for the development of decompensated heart failure (HR 0.37, 95% CI 0.15–0.93) and cardiovascular events (HR 0.63, 95% CI 0.41–0.97). Interestingly, fewer episodes of intradialytic hypotension were reported when ultrafiltration was intensified in the active arm compared with the control arm ($p < 0.001$). Finally, the authors concluded that the pulmonary ultrasound-guided ultrafiltration strategy effectively alleviated congestion with a good safety profile, without favorably impacting major cardiovascular outcomes[11] . Traditionally, a “safety” range for the ultrafiltration rate (10–13 mL/kg/h) has been established due to its association with mortality and adverse cardiovascular outcomes[12,13] . In a retrospective cohort of chronic hemodialysis patients published in 2016 in the *American Journal of Kidney Diseases*, it was found that regardless of the established target ultrafiltration rate ($\leq$10 vs. >10 and $\leq$13 vs. >13 mL/kg/h), exceeding 10 or 13 mL/kg/h was associated with higher mortality (HR 1.22 and 1.31, respectively); these findings remained consistent after adjusting for covariates such as sex, race, duration on hemodialysis, session length, and body composition. However, it is important to note that this was a non-randomized observational study conducted prior to the era of ultrasound- or bioimpedance-guided ultrafiltration[12]. Cardiorenal patients have specific characteristics, including a predominantly intravascular component of excess extracellular volume, increased filling pressures, and an inability to generate adequate diuresis; Furthermore, it is common practice to subject this patient population to a higher ultrafiltration rate, particularly in acute settings—for example, in the presence of pulmonary edema—as described by *John T. Daugirdas in* the fifth edition of the *Dialysis Manual* (0.5–1.2 L/h)[14] .

Problem Statement

Fluid overload in patients with Stage 5 Chronic Kidney Disease (CKD) on hemodialysis is the leading cause of hospital readmission and a critical determinant of adverse cardiovascular outcomes. Standard management involves a critical therapeutic limitation: while guidelines suggest conservative ultrafiltration (UF) rates (10–13 mL/kg/h) to avoid hemodynamic instability, suboptimal fluid removal perpetuates systemic congestion and venous hypertension. The latter, which can be assessed using advanced protocols such as VExUS, triggers a cascade of multiorgan dysfunction (hepatic, intestinal,

and renal) that worsens the short-term prognosis. Although in real-world clinical practice (especially during the first in-hospital session) UF rates exceeding 13 mL/kg/h are frequently used to urgently relieve congestion, this approach lacks solid scientific support. Currently, there is a lack of evidence from clinical trials comparing the efficacy and safety of a high-ultrafiltration strategy versus the standard approach. Therefore, it is imperative to determine whether aggressive decongestion, guided by objective ultrasound parameters, can optimize clinical outcomes without compromising patient stability, thereby transforming an empirical practice into an evidence-based strategy.

Alternative Hypothesis

Patients with intravascular congestion (ultrasound scores consistent with congestion) demonstrate similar tolerance and effectiveness with high ultrafiltration rates (>13 mL/kg/h) compared to the standard rate (10 mL/kg/h).

Null hypothesis

Patients with intravascular congestion (ultrasound scores consistent with congestion) show differences in tolerance and effectiveness when using high ultrafiltration rates (>13 mL/kg/h) compared to the standard rate (10 mL/kg/h).

Study Design

A 1:1, longitudinal, prospective, randomized, controlled equivalence trial

Population

Group 1 (intervention): Men and women >18 years of age requiring acute mechanical ultrafiltration due to intravascular congestion, with an ultrafiltration rate >13 mL/kg/h.

Group 2 (standard management): Men and women >18 years of age requiring acute mechanical ultrafiltration due to intravascular congestion, with an ultrafiltration rate of 10 mL/kg/h.

Rationale

The profile of patients with chronic kidney disease on renal replacement therapy (RRT) via hemodialysis who experience an episode of fluid overload and are readmitted to the hospital for this reason exhibit a significant component of intravascular hypervolemia and elevated cardiac filling pressures; in these patients, high ultrasound congestion scores may predict equivalence in terms of tolerance and therapeutic efficacy at ultrafiltration rates higher than those used in standard practice with intermittent ultrafiltration.

Primary Objective

1. To compare the incidence of episodes of intradialytic hypotension between the two groups (as an indicator of safety).
2. Compare improvements in ultrasound parameters of intravascular congestion and cardiac filling pressures (as an indicator of efficacy).
3. Compare clinical improvement using the mMRC dyspnea scale and the use of supplemental oxygen.

Secondary Objectives

1. Determine whether high scores for intravascular congestion and elevated cardiac filling pressures predict therapeutic tolerance and efficacy at ultrafiltration rates >13 mL/kg/h (and establish cutoff values).
2. Determine differences in length of hospital stay and days of supplemental oxygen use.
3. Correlate congestion scores with the ultrafiltration volume during the intervention dialysis session.
4. Compare improvements in blood pressure control between the two groups.
5. Explore whether variables such as LVEF, natriuretic peptides, and pre-dialysis blood pressure modify the clinical response to the ultrafiltration profile used.
6. Analyze changes in ultrasound variables and natriuretic peptides within the first 24 hours following the intervention session.

Inclusion Criteria

1. Men and women >18 years of age

1.1. Stage 5 chronic kidney disease (CKD) patients on hemodialysis who have been on renal replacement therapy (RRT) for at least 3 months and require mechanical ultrafiltration due to fluid overload.

1.2. First in-hospital session.

1.3. Echocardiographic evidence of elevated filling pressures.

1.3.1. Peak tricuspid regurgitation velocity (TRV), max. IVT; septal and lateral tissue Doppler, E/A, E/e', mitral pulsed wave.

1.4. Ultrasound evidence of intravascular congestion (assessed by a nephrologist or cardiologist):

1.4.1. Evidence of a diffuse B-pattern on echocardiography (dichotomized into >15 o <15 B Lines).

1.4.2. Abnormal VExUS (inferior vena cava >2.0, suprahepatic D>S or reverse S, portal pulsatility >30%, 30–50%, and >50%, renal pulsatility with a discontinuous pattern).

1.5. Hemodynamic stability with blood pressure of at least ≥120/80.

Exclusion criteria

1. Patients with hemodynamic instability (<100/60)
2. Patients in cardiogenic shock
3. Patients in septic or distributive shock
4. Patients with acute coronary syndrome
5. Patients with severe pericardial effusion
6. Patients with known right ventricular dysfunction
7. Patients with concomitant gastrointestinal bleeding
8. Patients with a poor window for ultrasound evaluation
9. Patients with known pulmonary disease

10. Patients with severe valvular heart disease (mitral and/or aortic)
11. Pregnant women

Sample size calculation

A formula was used to estimate equivalence between two proportions. An adequate tolerance for hemodialysis of 90% under standard therapy was considered the equivalence value. The equivalence margin was set at ±10%. An alpha value of 0.05 (95% confidence level) and a beta value of 0.2 (90% power) were used. Based on these data, the required sample size per group is at least 35 participants.

$$n = \frac{2pq(K)}{\epsilon^2}$$

$$n = \frac{2(0.90)(0.10)(1.96 + 1.28)^2}{(0.10)^2}$$

$$n = \frac{2(0.09)(3.24)^2}{0.01}$$

$$n = \frac{0.18(10.4976)}{0.01}$$

$$n = \frac{1.889568}{0.01}$$

$$n \approx 34.2$$

Methodology

Hospitalized patients with a history of Stage 5 Chronic Kidney Disease (CKD) who have been on hemodialysis for at least 3 months and require mechanical ultrafiltration due to fluid overload will be recruited and randomly assigned to either the standard ultrafiltration rate group or the high ultrafiltration rate group.

Informed consent will be obtained through a rigorous process that ensures the participant's autonomy and understanding. Once the patient meets the inclusion criteria following initial stabilization during hospitalization, the principal investigator or a duly trained co-investigator will approach the candidate in an environment that ensures the privacy and tranquility necessary for decision-making. The nature of the study will be explained clearly, simply, and in non-technical language, emphasizing the voluntary nature of participation and the randomization methodology for the ultrafiltration groups, as well as a

detailed risk analysis (specifically the risks associated with high versus standard ultrafiltration rates) and the potential benefits of ultrasound-guided decongestion. The patient (or, if applicable, their next of kin or legal representative) will be given sufficient time to read the document, ask questions, and clarify any doubts regarding the procedures (ultrafiltration, ultrasound, echocardiography, and sample collection). They will be informed that they may withdraw from the study at any time without this affecting their current or future medical care. After confirming their willingness to participate, the written Informed Consent form will be signed. To attest to the transparency of the process and ensure the protection of the research subject, two witnesses will be present during the signing; they will sign the document along with the patient (or their legal representative, if applicable) and the researcher.
Upon completion of the signing process, the participant will be given an original duplicate copy of the informed consent document, duly signed by all parties, for their personal records. The original document will remain in the investigator's file as part of the research record, ensuring traceability and regulatory compliance.

Patients will be assigned to one of the two groups via block randomization. The randomization sequence will be kept blinded to all participants except the principal investigator.

Patients will be weighed in kilograms to calculate the weight-adjusted ultrafiltration rate (mL/kg/h) using a previously calibrated scale; and bedside bioimpedance will be performed to estimate dry weight and calculate excess extracellular volume. Patients in the standard ultrafiltration group will be prescribed an ultrafiltration rate of 10 mL/kg/h, and patients in the high ultrafiltration group will be assigned a rate >13 mL/kg/h. The duration of the sessions for both groups will be determined by the treating nephrologist. Blood and dialysate flow rates, as well as sodium and potassium levels, will be prescribed according to the treating nephrologist's judgment based on the individual case assessment. The temperature will be set at 35.0–35.5 °C in both groups. The comparison of efficacy and tolerability will be evaluated only within the first 24 hours following the first mechanical ultrafiltration session. With regard to efficacy, the change in ultrasonographic congestion variables and their correlation with clinical hemodynamic and respiratory improvement will be assessed.

A coded and confidential database will be created in Microsoft Excel, into which the information collected from the study participants will be entered for subsequent statistical analysis; this database will be secured with a password to which only the principal investigator and co-investigators will have access.

Procedures for Evaluating Objectives

To evaluate the primary and secondary endpoints, the following standardized procedures will be performed during the first 24 hours of the intervention:

A. Evaluation of the Primary Endpoint (Safety and Efficacy):
    a. Monitoring of Intradialytic Hypotension (IDH): Blood pressure (BP) and heart rate (HR) will be recorded automatically every 15–30 minutes throughout the hemodialysis session. An IDH episode will be defined according to KDOQI criteria (a drop in systolic blood pressure ≥20 mmHg or mean arterial pressure >10 mmHg associated with clinical symptoms such as dizziness, cramps, or nausea requiring intervention).
    b. Dynamic Ultrasound Protocol:
        i. Pre-intervention: A pulmonary ultrasound (8-zone protocol) will be performed, counting the total number of B-lines; an echocardiographic assessment by the Cardiology Department will be conducted to estimate filling pressures; and the VExUS protocol (inferior vena cava diameter and Doppler flow patterns in the hepatic, portal, and renal veins) will be used to assign a congestion grade (0–3).
        ii. Post-procedure: The ultrasound assessment will be repeated exactly 24 hours after the procedure to quantify the reduction in B-lines, changes in cardiac filling pressures, and changes in the VExUS score. The pulmonary ultrasound reassessment and VExUS protocol will be performed by a nephrologist other than the one who scheduled the session, to ensure blinded evaluation, while the echocardiographic reassessment will be performed by the same evaluator. Improvement will be defined as a reduction of at least 1 grade on the VExUS scale, a 30% decrease in the B-line count, and improvement in echocardiographic parameters related to increased cardiac filling pressures.
    c. Respiratory Clinical Assessment: The mMRC dyspnea scale will be applied, and the fraction of inspired oxygen (FiO_2) or supplemental oxygen flow (liters per minute) will be recorded before the session and 24 hours afterward.

B. Evaluation of Secondary Endpoints
    a. Prediction and Tolerance Analysis: Findings regarding cardiac filling pressures (E/e' and other echocardiographic parameters obtained by the Cardiology department) and baseline VExUS scores will be correlated with the presence or absence of adverse

events during the assigned UF rate (>13 mL/kg/h in the high-rate group). Using ROC curves, we will seek to establish the congestion cutoff value that predicts hemodynamic stability despite high ultrafiltration rates.

b. Clinical Follow-up and Hospital Stay: The dates of hospital admission and discharge will be recorded, as well as the total number of days requiring supplemental oxygen. These data will be extracted from the medical record once the patient is discharged.
c. Correlation Between Volume and Blood Pressure Control: The total scheduled ultrafiltration volume will be recorded and compared to the volume achieved at the end of the session. Pre-dialysis and post-dialysis blood pressure readings will be compared at 24 hours to assess the impact on short-term blood pressure control.
d. Biomedical and Echocardiographic Variables: Results for natriuretic peptides (NT-proBNP) measured prior to the session and 24 hours after the intervention will be collected. The left ventricular ejection fraction (LVEF) reported by the Cardiology department will be included to perform subgroup analyses and determine whether systolic dysfunction modifies the response to the aggressive regimen.

Variable / Procedure	Baseline (Pre-intervention)	During the Session (HD)	Post-intervention (24 hrs)
Informed Consent Form	**X**		
Weight and Bioimpedance (VEC)	**X**		**X**
VExUS and Pulmonary Protocol (8 zones)	**X**		**X**
Echocardiogram (Filling Pressures/LVEF)	**X**		**X**
mMRC Dyspnea Scale and FiO2	**X**		**X**
NT-proBNP (Natriuretic Peptides)	**X**		**X**
Blood Pressure and Heart Rate Monitoring	**X**	**X** (every 15–30 min)	**X**
Hypotension Log (HID)		**X**	

Objective Risk-Benefit Analysis

High vs. Standard Ultrafiltration Rate. The titration of the ultrafiltration (UF) rate in this protocol will be based on objective parameters of intravascular congestion (congestion ultrasound); however, it is recognized that the proposed high profile could exceed the standard safety range (often set at <13 mL/kg/h or based on baseline hemodynamic stability).

The following is a comparative analysis of the potential risks involved:

A. Risks Associated with a High Ultrafiltration Profile (Intervention):
    a. The main risk lies in the possibility of exceeding the plasma recruitment rate, which can lead to: Hemodynamic Instability: Increased incidence of intradialytic hypotension (IDH), which could compromise perfusion of critical organs. Myocardial Stunning: Acute and repetitive hypovolemic stress can induce transient ischemia and, in the long term, myocardial fibrosis. Loss of Residual Renal Function (RRF): Renal hypoperfusion secondary to high UF is a known risk factor for an accelerated decline in residual diuresis in patients with chronic kidney disease. Ischemic Events: Increased risk of mesenteric ischemia or cerebrovascular events in patients with pre-existing vascular disease.
B. Risks of the Standard Ultrafiltration Profile (Control):
    a. Although standard management is perceived as “safer” in the short term, it carries inherent risks due to potentially suboptimal fluid removal: Persistent Systemic Congestion: Risk of acute pulmonary edema and the need for mechanical ventilation. Congestion-Induced Organ Dysfunction: Venous hypertension (assessed by VExUS) can cause hepatic, intestinal, and renal congestion, perpetuating organ damage. Cardiovascular Morbidity and Mortality: A chronic state of volume overload is an independent predictor of left ventricular hypertrophy and cardiovascular death. It is now established that the presence of clinical or subclinical volume overload following an acute exacerbation represents the primary risk factor for major adverse cardiovascular outcomes and mortality.

Rationale and Mitigation Measures: The use of a high ultrafiltration profile in this study is justified by the use of intravascular congestion ultrasonography as a dynamic guide, allowing for , personalized

adjustment that a conventional fixed rate does not offer. To mitigate the risks described, the following safeguards will be implemented:

A. Close Monitoring: Continuous clinical and hemodynamic assessment during ultrafiltration sessions.
B. Criteria for Interruption: Discontinuation of therapy will be considered in any of the following scenarios:
    - Intradialytic hypotension: a drop in systolic blood pressure of >20 mmHg or a drop in mean arterial pressure (MAP) of >10 mmHg accompanied by symptoms of organ hypoperfusion requiring intervention
    - Symptomatic arrhythmic events documented during continuous cardiac monitoring: supraventricular tachycardia, atrial fibrillation, ventricular tachycardia, or ventricular fibrillation.
    - Neurological events: altered level of consciousness, signs and/or symptoms of focal neurological involvement.
C. Adverse Event Monitoring: All adverse events will be documented and reported to the Ethics Committee within the timeframes stipulated by regulations.
D. Safety Thresholds: An ultrafiltration rate of >13 and ≤15 mL/kg/h will be established as the safety threshold.

Statistical Analysis

The normality of the variables will be analyzed using the Shapiro-Wilk test. Normal continuous data will be expressed as means and standard deviations; non-normal data as medians and interquartile ranges. Categorical data will be presented as frequencies. For the comparison of categorical data, the chi-square test will be used for unpaired data and the McNemar test for paired data. Paired bivariate comparisons will be tested using the paired Student's t-test and the Wilcoxon test. Pearson's or Spearman's correlation will be performed depending on normality. For multiple comparisons of paired data, repeated-measures ANOVA or the Friedman test will be used, depending on normality. The Mauchly sphericity test will be performed to assess the sphericity of the ANOVA; if this assumption is not met, a Greenhouse-Geisser correction will be applied. The quantitative behavior of C-peptide over time will be analyzed graphically using curves, and results will be compared using quartiles. A p-value ≤ 0.05 will be considered statistically significant for inferential tests. These analyses will be performed using the SPSS V.24 statistical software.

Confidentiality and Protection of Personal Data

The study will be conducted in accordance with the principles of the Helsinki Declaration, as last revised, and will comply with the current ethical standards set forth in Mexico's General Health Law on Health Research. It is classified as research involving more than minimal risk, as it is a clinical trial that involves prescribing an ultrafiltration rate higher than the standard rate.

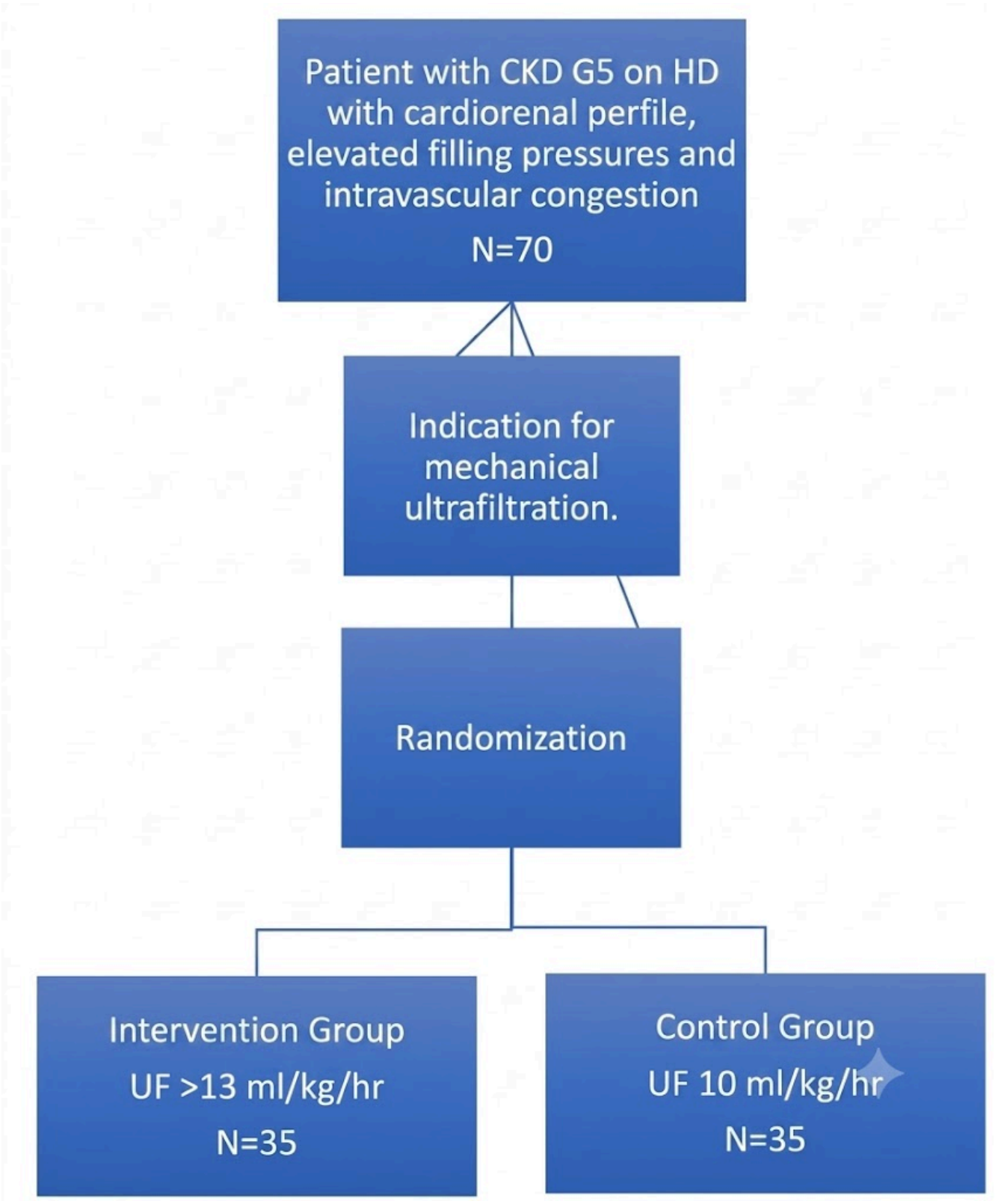
Data confidentiality will be ensured by assigning a unique identification code to each patient, guaranteeing that the subjects' identities will not be disclosed at any stage of the analysis or publication of results. The original database, which links the codes to the patients' names, will be stored in a password-protected encrypted electronic file, to which only the principal investigator and co-investigators will have access.

The data obtained from the ultrasound assessment of congestion will be used exclusively for the purposes of this research. Personal information will be handled in strict compliance with the Federal Law on the Protection of Personal Data Held by Private Parties, ensuring that the processing of sensitive data is relevant and limited to the objectives of the protocol.

Regulatory Framework and Ethical Considerations

This study will strictly adhere to current national and international regulations governing clinical research. It will be conducted in accordance with the ethical principles of the Declaration of Helsinki (in its most recent version) and the Good Clinical Practice (GCP) Guidelines of the International Council for Harmonization (ICH). At the national level, the protocol will comply with the provisions of the General Health Law and its Regulations on Health Research, as well as with NOM-012-SSA3-2012, which establishes the criteria for conducting health research projects involving human subjects.

Before carrying out any procedure related to the study, this protocol must receive favorable approval from the following bodies: the Research Ethics Committee (CEI) and the Research Committee (CI), to ensure the protection of participants' rights, safety, and well-being, and to validate the methodological soundness and scientific feasibility of the project, respectively.


Patient with CKD G5 on HD with cardiorenal perfile, elevated filling pressures and intravascular congestion
N=70
Indication for mechanical ultrafiltration.
Randomization
Intervention Group
UF >13 ml/kg/hr
N=35
Control Group
UF 10 ml/kg/hr
N=35

List of Variables

Variable	Variable Type	Description/Definition
Age	Quantitative	In years
Gender	Qualitative	Male or Female
Heart rate	Quantitative	Beats per minute
Systolic blood pressure	Quantitative	Systolic blood pressure in millimeters of mercury
Diastolic blood pressure	Quantitative	Diastolic blood pressure in millimeters of mercury
Mean blood pressure	Quantitative	Calculated mean blood pressure
Diuresis	Quantitative	Urine volume in milliliters
Weight	Quantitative	In kilograms (kg)
Height	Quantitative	In Meters (Mts)
Oxygen Saturation (Pulse Oximetry)	Quantitative	Digital oxygen saturation percentage
Supplemental oxygen flow	Quantitative	1–15 L/min
Oxygen supplementation device	Qualitative	Nasal prongs, mask, high-flow nasal cannula, invasive mechanical ventilation, noninvasive mechanical ventilation
Fraction of Inspired Oxygen (FiO2%)	Quantitative	Percentage of FiO2 administered: 21% (room air) – 100%
Jugular venous pulse	Quantitative	In centimeters, semi-Fowler's position 30°–45°, measured from the manubrium
mMRC dyspnea scale	Qualitative, categorical	Assesses physical disability caused by dyspnea. mMRC 0: No dyspnea except during intense exercise. mMRC 1: Dyspnea when walking briskly or

		climbing a gentle slope. mMRC 2: Inability to keep pace with others on level ground, or need to rest while walking at one's own pace. mMRC 3: Dyspnea forces to stop and rest after walking about 100 meters or for a few minutes on level ground. mMRC 4: Dyspnea with minimal physical exertion or dyspnea at rest.
Lower extremity edema	Qualitative, Categorical	Degree of edema ranging from +/++++ to ++++/++++
Intradialytic Hypotension	Qualitative, categorical	A decrease in systolic blood pressure >20 mmHg or a drop in mean arterial pressure >10 mmHg accompanied by symptoms of organ hypoperfusion requiring intervention
Duration of hemodialysis/ultrafiltration session	Quantitative	Time in hours of hemodialysis/mechanical ultrafiltration
Qs (Blood flow)	Quantitative	Blood flow rate at which the blood column will be drawn through the vascular access to undergo the hemodialysis/ultrafiltration session
Qd (Dialysate flow)	Quantitative	The flow rate of the dialysate solution to which the blood will be exposed in countercurrent flow through a transport membrane (filter) during a hemodialysis session.
Ultrafiltration rate	Quantitative	Rate of water removal per kilogram of body weight per hour of hemodialysis/ultrafiltration session

Net ultrafiltrate	Quantitative	Volume of water removed in milliliters (mL) per intermittent ultrafiltration session
Total ultrafiltrate	Quantitative	Cumulative volume of water removal in milliliters (mL) during an intermittent ultrafiltration session, including fluid intake during hospitalization.
Pulmonary US score	Quantitative	Average number of B-lines in the 8-field assessment
VExUS Protocol Score	Qualitative, categorical	0: no organic congestion, 1: mild organic congestion, 2: moderate organic congestion, 3: severe organic congestion
● Inferior Vena Cava Collapsibility	Quantitative	Diameter of the inferior vena cava during inspiration and expiration in centimeters
● Suprahaptic pulsatility pattern	Qualitative, categorical	Pulsatility pattern of suprahepatic veins: S>D, D>S, and reverse S-wave
● Portal pulsatility	Quantitative	Portal pulsatility index by pulsed Doppler ultrasound, $\frac{(\text{Max Velocity} - \text{Min Velocity})}{\text{Max Velocity}} \times 100$
● Intrarenal pulsatility	Qualitative, categorical	Continuous venous pattern, biphasic discontinuous venous pattern, monophasic discontinuous venous pattern
Serum creatinine	Quantitative	Blood creatinine level in mg/dL
Blood Urea Nitrogen (BUN)	Quantitative	BUN level in mg/dL
Serum uric acid	Quantitative	Uric acid level in mg/dL
Serum albumin	Quantitative	Blood albumin level in mg/dL
Serum NT-pro-BNP	Quantitative	Level of the molecule in pg/mL
Serum sodium	Quantitative	Blood sodium level in mEq/L

Serum potassium	Quantitative	Potassium level in the blood in mEq/L
Serum chloride	Quantitative	Chloride level in the blood in mEq/L
Serum phosphorus	Quantitative	Serum phosphorus level in mEq/L
Serum pH	Quantitative	pH level in blood (from arterial or venous blood gas analysis)
Serum HCO_3 (bicarbonate)	Quantitative	Bicarbonate level in the blood as measured by arterial or venous blood gas analysis
Congestive Heart Failure	Qualitative	Presence of signs and symptoms with objective evidence of cardiac dysfunction
Chronic Kidney Disease	Qualitative, Categorical	According to TFG, abnormalities in renal anatomy and/or function for at least 3 months
Peak Tricuspid Regurgitation Velocity	Quantitative	Maximum velocity of blood flowing backward from the right ventricle to the right atrium during cardiac systole
Atrial Diameter	Quantitative	Atrial diameter in millimeters
E/e' Ratio	Quantitative	Echocardiographic parameter used to estimate left ventricular filling pressures. A key tool for diagnosing diastolic dysfunction. E-wave: Measures the maximum velocity of blood entering the ventricle at the start of filling (rapid phase). It is measured in the mitral valve flow. e' wave: Measures the rate of stretching or relaxation of the heart muscle (tissue) itself.
Left Ventricular Ejection Fraction (LVEF) – Estimated	Quantitative	Subjective assessment through direct visualization of the percentage of blood ejected by the left ventricle. Preserved, Slightly reduced, and Reduced

Left Ventricular Ejection Fraction (LVEF) measured	Quantitative	Using the Simpson method. Percentage of blood ejected by the left ventricle with each heartbeat. Preserved, Slightly reduced, and Reduced
Cardiac output (CO)	Quantitative	Volume of blood that the heart pumps into the systemic circulation in one minute. CO = Heart rate × Stroke volume. Expressed in ml/min
Cardiac Power Output (CPO)	Quantitative	A hemodynamic parameter that measures the total energy generated by the heart to pump blood. CPO = Mean Arterial Pressure × CO / 451. It is expressed in watts (W)

References

1. McCallum, W., & Testani, J. M. (2023). Updates in cardiorenal syndrome. The Medical Clinics of North America, 107(4), 763–780. https://doi.org/10.1016/j.mcna.2023.03.011
2. Rangaswami, J., Bhalla, V., Blair, J. E. A., Chang, T. I., Costa, S., Lentine, K. L., Lerma, E. V., Mezue, K., Molitch, M., Mullens, W., Ronco, C., Tang, W. H. W., McCullough, P. A., & American Heart Association Council on the Kidney in Cardiovascular Disease and Council on Clinical Cardiology. (2019). Cardiorenal syndrome: Classification, pathophysiology, diagnosis, and treatment strategies: A scientific statement from the American Heart Association. Circulation, 139(16), e840–e878. https://doi.org/10.1161/CIR.0000000000000664
3. Costanzo, M. R., Negoianu, D., Jaski, B. E., Bart, B. A., Heywood, J. T., Anand, I. S., Smelser, J. M., Kaneshige, A. M., Chomsky, D. B., Adler, E. D., Haas, G. J., Watts, J. A., Nabut, J. L., Schollmeyer, M. P., & Fonarow, G. C. (2016). Aquapheresis versus Intravenous Diuretics and Hospitalizations for Heart Failure. JACC. Heart Failure, 4(2), 95–105. https://doi.org/10.1016/j.jchf.2015.08.005
4. Bart, B. A., Goldsmith, S. R., Lee, K. L., Givertz, M. M., O'Connor, C. M., Bull, D. A., Redfield, M. M., Deswal, A., Rouleau, J. L., LeWinter, M. M., Ofili, E. O., Stevenson, L. W., Semigran, M. J., Felker, G. M., Chen, H. H., Hernandez, A. F., Anstrom, K. J., McNulty, S. E., Velazquez, E. J., … Heart Failure Clinical Research Network. (2012). Ultrafiltration in decompensated heart failure with cardiorenal syndrome. The New England Journal of Medicine, 367(24), 2296–2304. https://doi.org/10.1056/NEJMoa1210357
5. Werns, S. W. (2008). Ultrafiltration versus intravenous diuretics for patients hospitalized for acute decompensated heart failure. The Year Book of Critical Care Medicine, 2008, 42–44. https://doi.org/10.1016/s0734-3299(08)70470-2
6. Leskovar, B., Furlan, T., Mihelcic, G., & Lainscak, M. (2025). Sustained low-efficiency dialysis in congested patients with advanced heart failure. Cardiorenal Medicine, 15(1), 1–22. https://doi.org/10.1159/000549006
7. Zachariah, V. K., Sunitha, V. C., Ramachandran, N., Vairappan, B., Parameswaran, S., & Priyamvada, P. S. (2024). Does lung ultrasound-guided ultrafiltration lead to better outcomes in acute kidney injury requiring intermittent hemodialysis: A randomized controlled trial. Hemodialysis International. International Symposium on Home Hemodialysis, 28(4), 435–443. https://doi.org/10.1111/hdi.13170
8. Allinovi, M., Palazzini, G., Lugli, G., Gianassi, I., Dallari, L., Laudicina, S., Gregori, M., Rossi, F., Giannerini, D., Cutruzzulà, R., Dervishi, E., Biagini, M., & Cirami, C. L. (2022). Pre-dialysis B-

line quantification via lung ultrasound is a useful method for evaluating dry weight and predicting the risk of intradialytic hypotension. Diagnostics (Basel, Switzerland), 12(12), 2990. https://doi.org/10.3390/diagnostics12122990

9. Sars, B., van der Sande, F. M., & Kooman, J. P. (2020). Intradialytic hypotension: Mechanisms and outcome. Blood Purification, 49(1–2), 158–167. https://doi.org/10.1159/000503776
10. Kuipers, J., Verboom, L. M., Ipema, K. J. R., Paans, W., Krijnen, W. P., Gaillard, C. A. J. M., Westerhuis, R., & Franssen, C. F. M. (2019). The prevalence of intradialytic hypotension in patients on conventional hemodialysis: A systematic review with meta-analysis. American Journal of Nephrology, 49(6), 497–506. https://doi.org/10.1159/000500877
11. Zoccali, C., Torino, C., Mallamaci, F., Sarafidis, P., Papagianni, A., Ekart, R., Hojs, R., Klinger, M., Letachowicz, K., Fliser, D., Seiler-Mußler, S., Lizzi, F., Wiecek, A., Miskiewicz, A., Siamopoulos, K., Balafa, O., Slotki, I., Shavit, L., Stavroulopoulos, A., … London, G. M. (2021). A randomized multicenter trial on a lung ultrasound-guided treatment strategy in patients on chronic hemodialysis with high cardiovascular risk. Kidney International, 100(6), 1325–1333. https://doi.org/10.1016/j.kint.2021.07.024
12. Assimon, M. M., Wenger, J. B., Wang, L., & Flythe, J. E. (2016). Ultrafiltration rate and mortality in maintenance hemodialysis patients. American Journal of Kidney Diseases: The Official Journal of the National Kidney Foundation, 68(6), 911–922. https://doi.org/10.1053/j.ajkd.2016.06.020
13. Flythe, J. E., Kimmel, S. E., & Brunelli, S. M. (2011). Rapid fluid removal during dialysis is associated with cardiovascular morbidity and mortality. Kidney International, 79(2), 250–257. https://doi.org/10.1038/ki.2010.383
14. Daugirdas, J. T. (2015). Dialysis Manual, 5e (5th ed.). Wolters Kluwer Health.