

Prevalence of Intradialytic Hypertension Among Patients Undergoing Maintenance Hemodialysis: A Single-Center Cross-Sectional Study Using Three Diagnostic Definitions

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Research Article

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Abstract

Background

Intradialytic hypertension (IDH) is a paradoxical increase in blood pressure during or immediately after hemodialysis and is associated with adverse cardiovascular outcomes. The reported prevalence varies substantially because no single diagnostic definition is universally applied. In this study, the prevalence of IDH was estimated using three reproducible definitions across six consecutive maintenance hemodialysis sessions.

Methods

This single-center cross-sectional analysis included 280 adults receiving maintenance hemodialysis. Pre- and post-dialysis systolic blood pressure (SBP) was evaluated over six consecutive sessions. IDH was defined as follows: A, any pre-to-post SBP increase in at least four of six sessions; B, an increase in the SBP ≥ 10 mmHg in at least four sessions; and C, an increase in the SBP ≥ 10 mmHg with a post-dialysis SBP ≥ 140 mmHg in at least four sessions. Prevalence was reported with Wilson 95% confidence intervals (CIs), and agreement was assessed using Cohen's kappa.

Results

The mean age was 49.5 ± 14.6 years; 168 (60.0%) participants were male, and 112 (40.0%) had diabetes mellitus. The mean session-averaged SBP increased from 138.7 ± 7.6 mmHg before dialysis to 146.1 ± 12.1 mmHg after dialysis. The prevalence was 69.6% (195/280; 95% CI 64.0–74.7) under definitions A and B and 60.0% (168/280; 95% CI 54.2–65.6) under definition C. Definitions A and B showed complete agreement ($\kappa = 1.00$); each agreed with definition C in 90.4% of participants ($\kappa = 0.79$).

Conclusions

The estimated IDH prevalence was high and decreased by 9.6 percentage points when a hypertensive-range post-dialysis threshold was met. The identical classification produced by definitions A and B reflects the polarized BP trajectories in this dataset. These findings underscore the importance of reporting precise operational criteria and validating source data before clinical interpretation.

Introduction

Blood pressure behavior during hemodialysis is clinically heterogeneous. Although most patients experience a decrease in blood pressure with ultrafiltration, a subgroup develops a reproducible increase in blood pressure during or immediately after treatment, typically termed intradialytic hypertension (IDH) [1–4]. IDH is associated with excess extracellular volume, intradialytic vascular resistance, endothelial

dysfunction, dialysate–serum sodium gradients, sympathetic activation, and renin–angiotensin–aldosterone system activity [2–6].

The prognostic importance of this phenotype extends beyond a single dialysis session measurement. In observational cohorts, increases in systolic blood pressure (SBP) during dialysis have been associated with increased interdialytic ambulatory blood pressure, hospitalization, cardiovascular events, and mortality [7–10]. However, prevalence estimates vary because studies have used different definitions, including any intradialytic rise, absolute increases in SBP of 5 or 10 mmHg, post-dialysis hypertension, or recurrence across multiple treatments [1, 3, 11]. A Kidney Disease: Improving Global Outcomes controversies report proposed that an increase in SBP > 10 mmHg from pre- to post-dialysis to the hypertensive range in at least four of six consecutive treatments should prompt further evaluation, while acknowledging the limited evidence base [3].

Definitely, ascertainment of dependent cases is especially important in descriptive single-center studies, where comparisons with external populations can otherwise be misleading. We therefore estimated the prevalence of IDH using three increasingly specific operational definitions across six consecutive treatments and quantified the agreement among definitions. The secondary objectives were to describe blood pressure trajectories and to explore unadjusted associations with sex and diabetes mellitus.

Methods

Study design and setting

This was a single-center cross-sectional study conducted in the maintenance hemodialysis unit at Kasturba Medical College, Mangaluru, India, from January 2026 to July 2026. All eligible patients who received maintenance hemodialysis during the study period were consecutively enrolled through convenience sampling. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) framework [12].

Participants

The analytic dataset included 280 adults undergoing maintenance hemodialysis. Patients were eligible for inclusion if they were aged ≥ 18 years, had end-stage kidney disease requiring maintenance hemodialysis for at least 3 months, were receiving hemodialysis two or three times per week, and had complete pre- and postdialysis blood pressure measurements available for six consecutive dialysis sessions.

Patients were excluded if they were receiving hemodialysis for acute kidney injury, had been hospitalized or had an active infection during the observation period, were pregnant, missed one or more of the six consecutive dialysis sessions required for assessment, or had incomplete pre- or post-dialysis blood

pressure measurements. Patients whose clinical or demographic data were insufficient for the analysis were also excluded.

The final analysis cohort consisted of 280 participants. No participants included in the analysis had missing data on age, sex, diabetes status, or any of the six paired pre- and post-dialysis blood pressure measurements.

Blood pressure measurement

Pre- and post-dialysis systolic (SBP) and diastolic (DBP) blood pressure were recorded for six consecutive hemodialysis treatments using an automated, noninvasive blood pressure monitor integrated into the Fresenius dialysis machine. An appropriately sized cuff was selected based on the patient's arm circumference and applied to the non-access arm whenever feasible. Blood pressure measurements were obtained with the patient in a seated or semi-recumbent position after approximately 5 minutes of rest. Pre-dialysis blood pressure was measured immediately before the initiation of hemodialysis and, whenever feasible, before vascular access needle insertion. Post-dialysis blood pressure was measured after completion of the dialysis session and after disconnection from the extracorporeal circuit before the patient left the dialysis station. If a measurement was considered unreliable because of patient movement, improper cuff placement, or an implausible value, the patient was allowed to rest, and the measurement was repeated; the repeated measurement was used for documentation. Measurements were performed by dialysis unit staff trained to follow the unit's standardized blood pressure measurement procedure.

For the primary analyses, only SBP was used because the recurrent intradialytic hypertension (IDH) definitions evaluated in this study were SBP-based. Mean pre- and postdialysis SBP values across the six consecutive treatments were calculated for descriptive reporting.

Operational definitions

Three prespecified sensitivity definitions were recalculated directly from the recorded SBP values:

Definition A (recurrent any-rise)

Post-dialysis SBP exceeded pre-dialysis SBP in at least four of six sessions.

Definition B (increase in recurrence ≥ 10 mmHg): The postdialysis SBP was at least 10 mmHg higher than the pre-dialysis SBP in at least four of the six sessions.

Definition C (recurrent hypertensive-range rise)

criteria for definition B were met, and post-dialysis SBP was ≥ 140 mmHg in at least four of six sessions.

Definition C was defined according to the prespecified study protocol as a recurrent pre- to post-dialysis increase in SBP, with a post-dialysis SBP ≥ 140 mmHg. This definition was intended to identify patients who demonstrated both a recurrent intradialytic rise in SBP and a post-dialysis blood pressure level within the hypertensive range. Because definitions and thresholds for intradialytic hypertension vary across the dialysis literature, the results for all three definitions were reported separately, without designating any single definition as the definitive clinical diagnostic criterion [1–3, 11].

Statistical analysis

Continuous variables are summarized as the mean $\pm$ standard deviation (SD) and median with interquartile range (IQR), and categorical variables are summarized as numbers and percentages. Prevalence estimates use Wilson 95% confidence intervals. Pairwise agreement was summarized as percent agreement and Cohen's kappa. Unadjusted subgroup comparisons by sex and diabetes status were performed using Pearson's chi-square test. Analyses were complete because no included variable was missing. Two-sided $P < 0.05$ was considered to indicate statistical significance. Because only age, sex, diabetes status, and BP measurements were available, no multivariable etiologic model was fitted; subgroup findings are exploratory and should not be interpreted causally.

Generative artificial intelligence assisted with language drafting and the generation of analysis code. The authors must independently verify the source data, statistical outputs, citations, and final text and remain fully accountable for the manuscript.

Ethics approval

The study protocol, entitled "Prevalence, risk factors and outcomes of intradialytic hypertension: a single center study," was approved by the Institutional Ethics Committee, Kasturba Medical College, Mangalore (IEC KMC MLR 03-2021/76) on 17 March 2021; the approval letter was issued on 18 March 2021. Written informed consent was obtained from all participants before their inclusion in the study. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional ethical guidelines.

Results

Participant characteristics and blood pressure profile

All 280 records in the supplied dataset were included. The mean age was 49.5 ± 14.6 years (median 53; IQR 38–62); 168 (60.0%) participants were male, and 112 (40.0%) had diabetes. Across the six sessions, the mean participant-level pre-dialysis SBP was 138.7 ± 7.6 mmHg, and the mean post-dialysis SBP was 146.1 ± 12.1 mmHg, corresponding to a mean pre-to-post change of $+7.4 \pm 7.6$ mmHg (Table 1).

Table 1
Participant characteristics and session-averaged
systolic blood pressure (N = 280)

Characteristic	Summary
Age, years	49.5 ± 14.6
Age, median (IQR), years	53 (38–62)
Male sex, n (%)	168 (60.0)
Diabetes mellitus, n (%)	112 (40.0)
Pre-dialysis SBP, mmHg	138.7 ± 7.6
Post-dialysis SBP, mmHg	146.1 ± 12.1
Preto-post SBP change, mmHg	+ 7.4 ± 7.6

The values are the means ± SDs unless otherwise indicated. IQR, interquartile range; SBP, systolic blood pressure.

Prevalence under three definitions

Definitions A and B each identified 195 participants (69.6%; 95% CI 64.0–74.7). The stricter definition C identified 168 participants (60.0%; 95% CI 54.2–65.6), an absolute reduction of 9.6 percentage points compared with definitions A and B (Table 2; Fig. 1).

Table 2
Prevalence of intradialytic hypertension under three operational definitions

Definition	Criterion across six sessions	Cases/N	Prevalence, % (95% CI)
A	Any SBP rise in ≥ 4 sessions	195/280	69.6 (64.0–74.7)
B	SBP rise ≥ 10 mmHg in ≥ 4 sessions	195/280	69.6 (64.0–74.7)
C	SBP rise ≥ 10 mmHg and post-SBP ≥ 140 mmHg in ≥ 4 sessions	168/280	60.0 (54.2–65.6)

CI, confidence interval; SBP, systolic blood pressure.

Agreement between definitions

Definitions A and B classified every participant identically (100% agreement; $\kappa = 1.00$). Definition C agreed with each of the broader definitions for 253 of 280 participants (90.4%; $\kappa = 0.79$); 27 participants met definitions A and B but did not reach the post-dialysis hypertensive-range criterion in definition C (Table 3).

Table 3
Pairwise agreement between intradialytic hypertension definitions

Comparison	Both negative	First positive/second negative	First negative/second positive	Both positive	Agreement, %	κ
A vs B	85	0	0	195	100.0	1.00
A vs C	85	27	0	168	90.4	0.79
B vs C	85	27	0	168	90.4	0.79

Exploratory subgroup analyses

Under definition A, the prevalence was 29.5% among women and 96.4% among men ($P < 0.001$), and 50.6% among participants without diabetes versus 98.2% among those with diabetes ($P < 0.001$). Similar large differences were present under definition C (Table 4; Fig. 2). These results are unadjusted. Given the unusually strong separation and limited covariate set, they require source-data verification and should be regarded as descriptive signals only.

Table 4
Exploratory unadjusted prevalence by sex and diabetes status

Definition	Subgroup	Cases/N	Prevalence, % (95% CI)	P value
A	Female	33/112	29.5 (21.8–38.5)	< 0.001
A	Male	162/168	96.4 (92.4–98.4)	
A	No diabetes	85/168	50.6 (43.1–58.1)	< 0.001
A	Diabetes	110/112	98.2 (93.7–99.5)	
C	Female	33/112	29.5 (21.8–38.5)	< 0.001
C	Male	135/168	80.4 (73.7–85.7)	
C	No diabetes	58/168	34.5 (27.8–42.0)	< 0.001
C	Diabetes	110/112	98.2 (93.7–99.5)	

P values are from Pearson chi-square tests for each two-level subgroup comparison.

Discussion

In this single-center cross-sectional dataset, the estimated IDH prevalence depended on whether a hypertensive-range post-dialysis threshold was needed. The two rise-based definitions classified 69.6% of the participants, whereas the strict recurrent hypertensive-range definition classified 60.0%. Thus, adding a post-dialysis SBP threshold excluded approximately 1 in 10 participants who otherwise had

recurrent increases of ≥ 10 mmHg. Agreement remained substantial, but the difference is clinically relevant for case finding, prevalence comparisons, and service planning.

The observed prevalence is substantially higher than the approximately 5–15% commonly reported for recurrent IDH phenotypes and the 16% reported in a Pakistani single-center study using a KDIGO-suggested definition [1, 2, 11]. Differences in thresholds, BP measurement procedures, dialysis prescriptions, volume status, antihypertensive use, case mix, and sampling can all contribute. However, definitional heterogeneity alone is unlikely to explain the entire contrast. The supplied data showed polarized trajectories: participants whose SBP generally increased by at least 10 mmHg, making definitions A and B identical. This distribution should be confirmed against dialysis records before external interpretation.

The reduction under definition C illustrates why a rise alone and a rise into the hypertensive range should not be treated interchangeably. A relative increase may indicate a hemodynamic nonresponse even when the absolute post-dialysis pressure is below a conventional hypertension threshold. In contrast, an absolute threshold selects a group with both directionally adverse change and elevated achieved pressure. Prior work has indicated that recurrent intradialytic increases are associated with higher interdialytic ambulatory BP and adverse outcomes, supporting further out-of-unit BP assessment rather than immediate treatment decisions based only on peridialytic measurements [3, 7–10].

Volume excess and heightened vascular resistance are prominent mechanistic candidates. Studies using bioimpedance and detailed hemodynamic assessment have linked IDH to extracellular volume overload and intradialytic vasoconstriction [5, 6]. Dialysate sodium exposure, endothelial mediators, and medication pharmacokinetics may also contribute [1–4]. Our dataset did not contain weight, ultrafiltration, dialysate composition, antihypertensive therapy, laboratory measures, or volume-assessment variables; therefore, mechanisms and modifiable risk factors could not be evaluated.

The striking unadjusted associations with male sex and diabetes should be interpreted cautiously. Their magnitude is atypically large, and confounding could not be addressed; extensive repetition of exact BP trajectories was detected. These findings should not be presented as independent risk factors unless the source dataset is reconciled and a clinically informed multivariable analysis is performed with adequate covariates.

Strengths and limitations

Strengths include evaluation across six consecutive sessions, explicit, reproducible definitions, confidence intervals for all prevalence estimates, and formal agreement analysis. Important limitations include the cross-sectional, single-center design; the absence of interdialytic or ambulatory BP confirmation; limited clinical covariates; the inability to assess mechanisms or outcomes; and a lack of information on measurement standardization and sampling. The ≥ 140 mmHg threshold used in definition C requires confirmation by protocol. Most importantly, only 25 unique six-session systolic BP trajectories were observed among 280 records, with extensive exact repetition; this may reflect

structured data generation, templating, transcription, or another data-management process and may necessitate verification against source records. Until resolved, the estimates should be regarded as provisional and should not be submitted as final clinical research findings.

Conclusions

The prevalence of IDH ranged from 60.0% to 69.6% depending on the operational definition. Requiring both a ≥ 10 mmHg increase from baseline and a post-dialysis SBP ≥ 140 mmHg reduced the prevalence by 9.6 percentage points. Explicit definition reporting materially improves comparability, but source data reconciliation and completion of clinical method details are essential before these unusually high estimates can support clinical or epidemiological conclusions.

Abbreviations

BP

blood pressure

CI

confidence interval

IDH

intradialytic hypertension

IEC

Institutional Ethics Committee

IQR

interquartile range

KDIGO

Kidney Disease:Improving Global Outcomes

SBP

systolic blood pressure

SD

standard deviation

STROBE

Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Ethics Committee, Kasturba Medical College, Mangalore (IEC KMC MLR 03-2021/76; meeting date 17 March 2021; approval letter dated 18 March 2021). Informed consent was obtained.

Consent for publication

Not applicable; no identifiable individual-level information is presented.

Competing interests

The authors declare that they have no competing interests.

Authors' information

Not applicable.

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Author Contribution

RN conceptualized the study, curated the data, and drafted the manuscript. RN contributed to the methodology, clinical supervision, formal analysis, interpretation, and critical revision. All the authors read and approved the final manuscript.

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Not applicable.

Data Availability

The deidentified dataset analyzed in the current study is available from the corresponding author upon reasonable request and is subject to institutional and ethical requirements.

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Figures

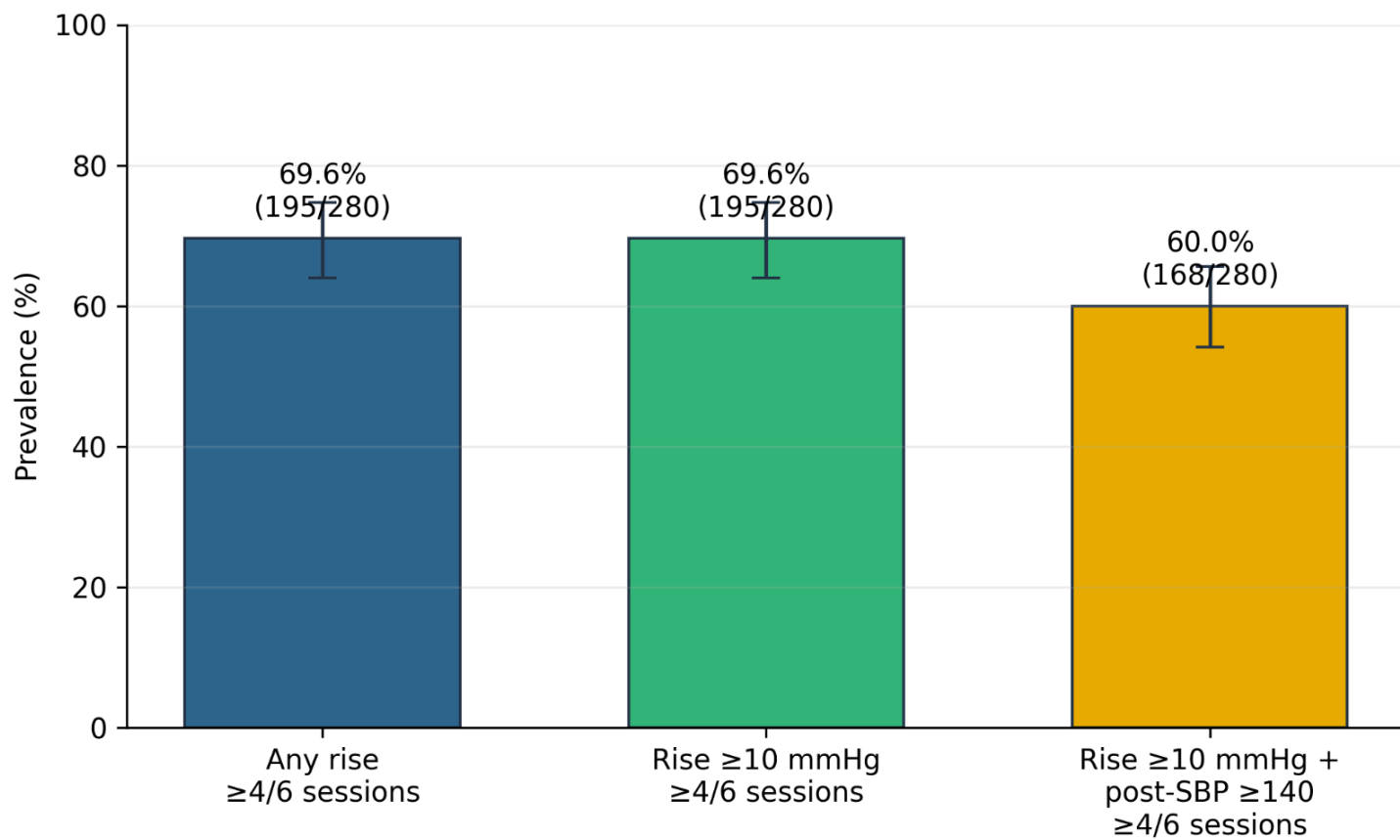


Figure 1

Prevalence of intradialytic hypertension using three operational definitions. The error bars indicate the Wilson 95% confidence intervals.

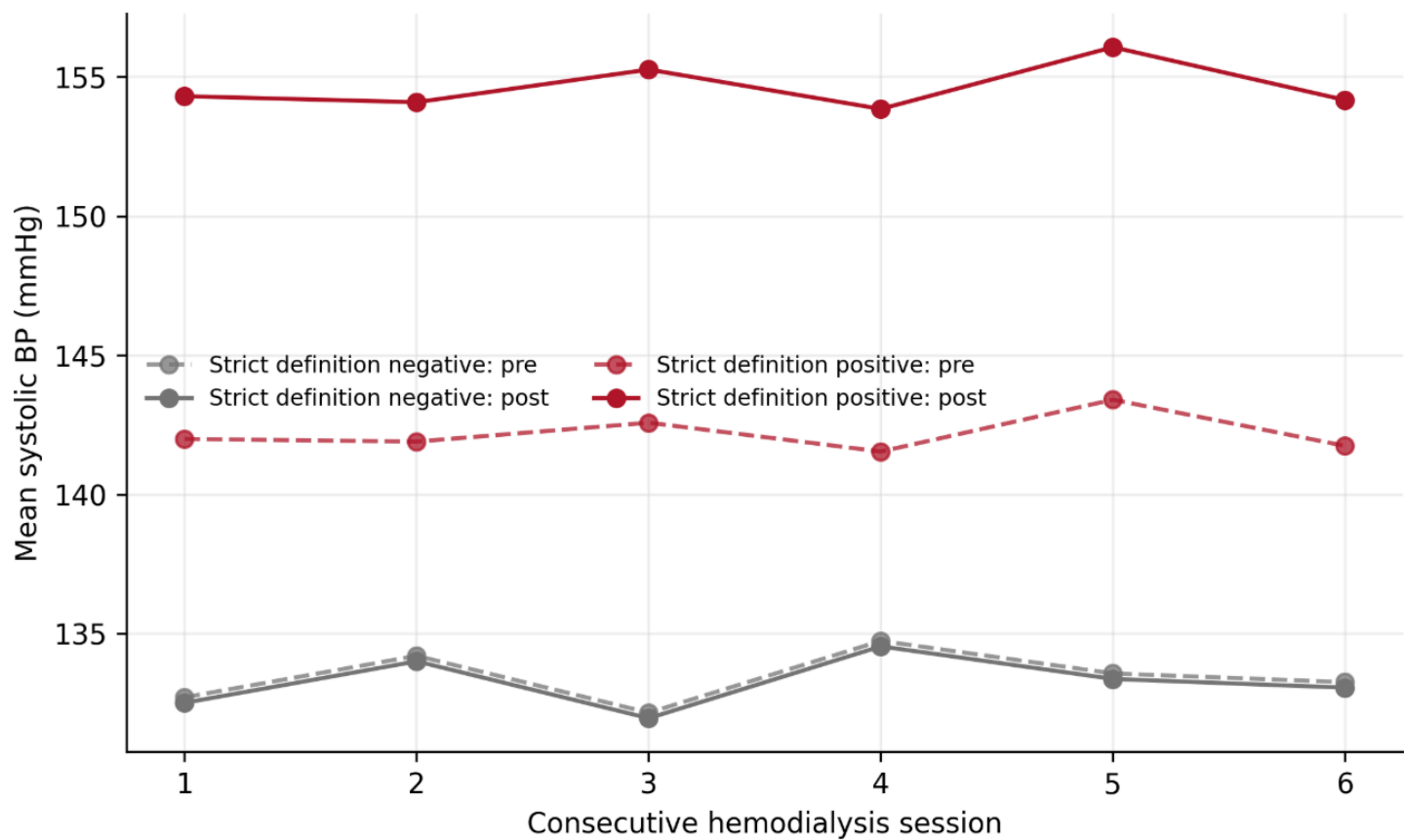


Figure 2

Mean pre- and post-dialysis systolic blood pressure across six consecutive sessions, stratified by the strict definition C. Lines summarize participant means and are descriptive; variability bars are omitted for clarity.