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Original Research Article

Impact of Dialysis Adequacy (Kt/V) on Morbidity and Mortality in Patients Receiving Maintenance Hemodialysis: A Prospective Observational Study from Eastern India

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Abstract:

Background: Dialysis adequacy is an important component of haemodialysis care in patients with chronic kidney disease (CKD). The delivered dose of dialysis, commonly assessed using Kt/V, may influence clinical outcomes, including cardiovascular complications, infections, hospitalization, and mortality.

Objective: To evaluate the association between dialysis adequacy, assessed using Kt/V, and clinical outcomes among patients with CKD undergoing maintenance haemodialysis.

Methods: This prospective observational study included 58 patients undergoing maintenance haemodialysis. Participants were classified into an adequate dialysis group (Kt/V ≥1.2; n=26) and an inadequate dialysis group (Kt/V <1.2; n=32). Clinical outcomes, including cardiovascular complications, infections, hospitalization, and mortality, were compared between the groups.

Results: Cardiovascular complications (50.0% vs 19.2%) and infections (43.8% vs 15.4%) were more frequent in the inadequate-Kt/V group than in the adequate-Kt/V group. Hospitalization episodes per patient were also higher (2.25 ± 1.12 vs 0.85 ± 0.78). Mortality was numerically higher (28.1% vs 7.7%), but the two-sided Fisher exact comparison was inconclusive (p=0.090). These unadjusted associations do not establish causation.

Conclusion: Inadequate dialysis, defined by a Kt/V below 1.2, was associated with a higher observed burden of adverse clinical outcomes in this study. Larger prospective studies with adequate adjustment for potential confounding factors are required to clarify the relationship between dialysis adequacy and patient outcomes.

Keywords: Chronic Kidney Disease; Haemodialysis; Dialysis Adequacy; Kt/V; Hospitalization; Mortality; Cardiovascular Complications.

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Introduction

Chronic kidney disease (CKD) is a major global health problem, and progression to kidney failure may require maintenance dialysis or transplantation [1,2]. Hemodialysis adequacy is commonly assessed using single-pool Kt/V urea, a dimensionless measure incorporating dialyzer urea clearance (K), treatment duration (t), and the volume of distribution of urea (V). The second-generation Daugirdas equation is widely used to estimate single-pool Kt/V from pre- and post-dialysis urea measurements and ultrafiltration [3].

The National Kidney Foundation's Kidney Disease Outcomes Quality Initiative (KDOQI) guideline provides recommendations for delivered dialysis dose and clinical monitoring [4]. Delivered dose can be affected by treatment duration, blood flow, vascular access function, missed or shortened sessions, and patient-related factors. Vascular access type and nutritional status may also be related to clinical outcomes, complicating interpretation of associations between Kt/V and morbidity [5,6].

Although dialysis adequacy is clinically important, observational comparisons require cautious interpretation because comorbidity, vascular access, nutrition, anaemia and other factors may influence both delivered dose and outcomes. The present study was described as a prospective observational evaluation of associations between Kt/V category and cardiovascular complications, infections, hospitalization burden and six-month all-cause mortality among adults receiving maintenance hemodialysis at JLNMCH, Bhagalpur.

Materials and Methods

Study design and setting: This prospective observational cohort was conducted at the Dialysis Unit of Jawaharlal Nehru Medical College and Hospital (JLNMCH), Bhagalpur, Bihar, India, during the reported study period of March–September 2026.

Participants: The cohort included 58 adults (≥18 years) with end-stage kidney disease receiving maintenance hemodialysis for at least three months before enrolment. Participants were recruited by convenience sampling. Exclusion criteria were acute kidney injury requiring temporary dialysis, active advanced malignancy, severe acute sepsis at baseline, and inability to provide informed consent.

Measurement of dialysis adequacy: Pre- and post-dialysis blood samples were collected monthly, according to the study documentation. Samples were obtained immediately before dialysis and at the end of the session using a slow-flow technique. Blood urea nitrogen was measured by an enzymatic urease method. Single-pool Kt/V was calculated using the second-generation Daugirdas equation [3]:

$$spKt/V = -\ln(R - 0.008 \times t) + (4 - 3.5 \times R) \times (UF/W)$$

where R is post-dialysis BUN divided by pre-dialysis BUN, t is treatment duration in hours, UF is ultrafiltration volume, and W is post-dialysis body weight. Participants were classified according to mean Kt/V as adequate (≥1.2; n=26) or inadequate (<1.2; n=32).

Outcomes

Outcomes included cardiovascular complications (acute coronary syndrome, congestive heart failure exacerbation, decompensated arrhythmia, or cerebrovascular accident), infectious complications (vascular-access infection, catheter-related bloodstream infection, or severe pneumonia), hospitalization frequency and cumulative hospital days, and all-cause mortality during the reported follow-up.

Statistical analysis: Continuous variables were summarized as mean ± standard deviation. Group comparisons of continuous variables were reported using independent-samples t-tests. For binary clinical outcomes, two-sided Fisher exact p-values were independently recalculated from the published group counts; the odds ratios and confidence intervals were retained as originally reported pending verification from participant-level records. Analyses were unadjusted and exploratory; no causal or independent association is inferred.

Results

Participant Characteristics: Of the 58 participants, 26 (44.8%) were classified in the adequate Kt/V group and 32 (55.2%) in the inadequate group. Overall mean age was 53.7 ± 9.0 years, and 33 participants (56.9%) were male. The main reported causes of kidney failure were diabetic nephropathy (44.8%), hypertensive nephrosclerosis (31.0%), and chronic glomerulonephritis (15.5%). Arteriovenous fistula use was more common in the adequate group (22/26; 84.6%) than in the inadequate group (19/32; 59.4%; reported p=0.038) (Table 1).

Table 1: Baseline characteristics

Characteristic	Overall (N=58)	Adequate Kt/V ≥1.2 (n=26)	Inadequate Kt/V <1.2 (n=32)	p-value
Age, years	53.7 ± 9.0	52.4 ± 8.6	54.8 ± 9.3	0.318
Male / female	33 (56.9%) / 25 (43.1%)	15 (57.7%) / 11 (42.3%)	18 (56.3%) / 14 (43.8%)	0.912
BMI, kg/m²	22.4 ± 3.1	22.8 ± 2.9	22.1 ± 3.3	0.395
Dialysis vintage, months	18.4 ± 11.2	19.2 ± 10.8	17.7 ± 11.6	0.612
Vascular access: AVF	41 (70.7%)	22 (84.6%)	19 (59.4%)	0.038
Vascular access: catheter	17 (29.3%)	4 (15.4%)	13 (40.6%)	

AVF, arteriovenous fistula; BMI, body mass index. Values are presented as reported aggregate data.

Biochemical and dialysis parameters: Mean Kt/V was reported as 1.35 ± 0.13 in the adequate group and 0.98 ± 0.14 in the inadequate group (p<0.001). The adequate group had higher reported mean haemoglobin (10.2 ± 1.2 vs 8.7 ± 1.1 g/dL) and serum albumin (3.8 ± 0.4 vs 3.1 ± 0.5 g/dL), both with reported p<0.001. Pre-dialysis BUN and serum creatinine were reported as higher in the inadequate group (Table 2). Figure 1A summarizes the reported group mean Kt/V values.

Table 2: Biochemical and dialysis parameters

Parameter	Overall (N=58)	Adequate Kt/V ≥1.2 (n=26)	Inadequate Kt/V <1.2 (n=32)	p-value
Delivered Kt/V	1.15 ± 0.23	1.35 ± 0.13	0.98 ± 0.14	<0.001
Pre-dialysis BUN, mg/dL	69.5 ± 18.2	58.4 ± 12.1	78.6 ± 16.4	<0.001
Serum creatinine, mg/dL	9.5 ± 2.3	8.2 ± 1.8	10.5 ± 2.1	<0.001
Serum albumin, g/dL	3.4 ± 0.6	3.8 ± 0.4	3.1 ± 0.5	<0.001
Haemoglobin, g/dL	9.4 ± 1.4	10.2 ± 1.2	8.7 ± 1.1	<0.001

BUN, blood urea nitrogen. Values are presented as reported aggregate data.

Morbidity, hospitalization and mortality: Cardiovascular complications occurred in 16/32 (50.0%) participants in the inadequate group and 5/26 (19.2%) in the adequate group (reported OR 4.20, 95% CI 1.25–14.07; recalculated two-sided Fisher exact p=0.027). Infectious complications occurred in 14/32 (43.8%) and 4/26 (15.4%), respectively (reported OR 4.28, 95% CI 1.19–15.34; recalculated Fisher exact p=0.025). Mean hospitalization frequency was 2.25 ± 1.12 versus 0.85 ± 0.78 episodes per patient (reported p<0.001) (Table 3).

Eleven deaths were reported during follow-up: 9/32 (28.1%) in the inadequate group and 2/26 (7.7%) in the adequate group (reported OR 4.70, 95% CI 0.91–24.23). A two-sided Fisher exact test recalculated from these counts gives p=0.090; thus the mortality comparison is statistically inconclusive.

The comparative frequencies of cardiovascular complications, infectious complications, hospitalization, and mortality are presented in Figure 1B.

Table 3: Clinical outcomes as reported in the study report

Outcome	Adequate Kt/V (n=26)	Inadequate Kt/V (n=32)	OR (95% CI)	Reported p-value
Cardiovascular complications	5 (19.2%)	16 (50.0%)	4.20 (1.25–14.07)	0.027*
Infectious complications	4 (15.4%)	14 (43.8%)	4.28 (1.19–15.34)	0.025*
Hospitalizations per patient, mean ± SD	0.85 ± 0.78	2.25 ± 1.12	Not reported	<0.001
All-cause mortality	2 (7.7%)	9 (28.1%)	4.70 (0.91–24.23)	0.090*

OR, odds ratio; CI, confidence interval; SD, standard deviation. Event counts and odds ratios are from the supplied study report. Two-sided Fisher exact p-values recalculated from counts: cardiovascular 0.027; infection 0.025; mortality 0.090. Original analysis outputs should be checked before submission.

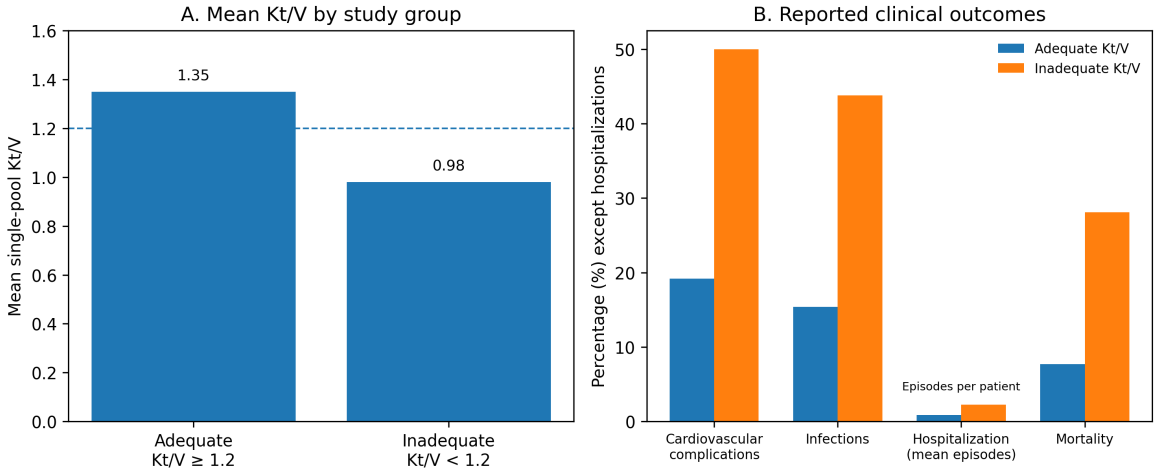


Figure 1: (A) Mean single-pool Kt/V in the adequate and inadequate dialysis groups. (B) Reported cardiovascular complications, infections, hospitalization frequency and six-month mortality by group. Hospitalization values are mean episodes per patient, not percentages.

Discussion

The present prospective observational study evaluated the association between dialysis adequacy, assessed using single-pool Kt/V, and clinical outcomes among patients receiving maintenance haemodialysis. More than half of the study participants (55.2%) had inadequate dialysis adequacy (Kt/V <1.2). Patients in the inadequate-Kt/V group experienced higher observed frequencies of cardiovascular complications, infectious complications, and hospitalization than those receiving adequate dialysis. These findings highlight the clinical relevance of dialysis adequacy assessment and are consistent with the importance placed on delivered dialysis dose in the Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines [4]. Nevertheless, the observed relationships should be interpreted as unadjusted associations rather than evidence of causality.

Cardiovascular complications were more frequent among patients with inadequate dialysis adequacy (50.0%) than among those with adequate dialysis (19.2%). This finding is clinically relevant because patients with advanced kidney disease experience a substantial cardiovascular disease burden. Sarnak et al. emphasized the importance of kidney disease as a cardiovascular risk factor and described the complex interactions between kidney dysfunction

and cardiovascular morbidity [8]. In the present study, differences in dialysis adequacy may have occurred alongside other cardiovascular risk factors, including anaemia, nutritional status, and underlying comorbidities. Therefore, although the observed association supports the importance of comprehensive cardiovascular assessment in maintenance haemodialysis patients, the independent contribution of Kt/V cannot be established from these unadjusted comparisons.

Infectious complications were also more frequent in the inadequate-Kt/V group (43.8%) than in the adequate-Kt/V group (15.4%). An important observation was the difference in vascular access between groups, with catheter use reported in 40.6% of patients with inadequate dialysis compared with 15.4% of those with adequate dialysis. This imbalance may have contributed to the observed difference in infectious complications. The KDOQI vascular access guideline emphasizes individualized vascular access planning and the importance of preventing access-related complications [5]. Consequently, the higher infection frequency observed in the present study may reflect a combination of dialysis-related and vascular access-related factors rather than inadequate dialysis dose alone.

The inadequate-Kt/V group also demonstrated lower mean haemoglobin and serum albumin concentrations than the adequate-Kt/V group. Mean haemoglobin was 8.7 ± 1.1 g/dL compared with 10.2 ± 1.2 g/dL, while mean serum albumin was 3.1 ± 0.5 g/dL compared with 3.8 ± 0.4 g/dL. These differences are clinically important because anaemia, nutritional status, inflammation, and comorbidity may influence outcomes among patients receiving maintenance haemodialysis. The KDOQI nutrition guideline emphasizes comprehensive nutritional assessment in patients with chronic kidney disease, including those undergoing dialysis [6]. Although serum albumin alone is not a definitive measure of nutritional status, its lower concentration in the inadequate-Kt/V group may indicate differences in underlying clinical condition. These findings reinforce the need to interpret dialysis adequacy alongside broader biochemical and clinical indicators.

Hospitalization frequency was substantially higher in the inadequate-Kt/V group, with a mean of 2.25 ± 1.12 episodes per patient compared with 0.85 ± 0.78 episodes per patient in the adequate-Kt/V group. This finding suggests a greater observed burden of healthcare utilization among patients with lower delivered dialysis adequacy. The higher frequencies of cardiovascular and infectious complications in the same group may have contributed to this difference. However, the available aggregate data do not establish whether these complications directly accounted for individual hospitalizations. These observations support the clinical value of comprehensive dialysis monitoring, including evaluation of delivered dialysis dose, vascular access, anaemia, nutritional indicators, and associated comorbidities [4–6].

All-cause mortality was numerically higher among patients with inadequate dialysis adequacy than among those with adequate dialysis (28.1% versus 7.7%). The reported odds ratio was 4.70 (95% CI: 0.91–24.23), while the recalculated two-sided Fisher exact test yielded a p-value of 0.090. Thus, although the observed mortality difference was clinically notable, it did not reach conventional statistical significance. The wide confidence interval indicates considerable uncertainty, likely influenced by the small sample size and limited number of deaths. The Hemodialysis (HEMO) Study conducted by Eknoyan et al. demonstrated that increasing dialysis dose above conventional targets did not necessarily produce an overall survival benefit in the studied population [9]. This evidence emphasizes that the relationship between delivered dialysis dose and survival is complex and that higher Kt/V values should not automatically be interpreted as guaranteeing improved survival. The present mortality findings should therefore be considered exploratory and interpreted cautiously.

Taken together, the findings indicate that inadequate dialysis adequacy was associated with a greater observed burden of morbidity and healthcare utilization in this cohort. The results reinforce the importance of routine assessment of delivered dialysis dose as part of comprehensive maintenance haemodialysis care, consistent with established clinical guidance [4]. However, dialysis adequacy should not be evaluated in isolation. Vascular access characteristics, anaemia, nutritional status, comorbidities, and other patient-related factors may influence both dialysis delivery and clinical outcomes. Accordingly, comprehensive and individualized patient assessment remains essential [4–6].

Future multicentre prospective studies with larger sample sizes, clearly defined follow-up periods, and prespecified multivariable analyses are warranted to investigate whether dialysis adequacy is independently associated with cardiovascular complications, infections, hospitalization, and mortality. Such investigations may help clarify the relative contributions of delivered dialysis dose and associated clinical factors to patient outcomes. [7].

Overall, this study contributes clinically relevant observational evidence regarding dialysis adequacy and adverse outcomes among patients receiving maintenance haemodialysis in Eastern India. The higher observed frequencies of cardiovascular complications, infections, and hospitalization among patients with inadequate Kt/V underscore the

importance of comprehensive dialysis care, while the statistically inconclusive mortality comparison highlights the need for larger, adequately powered investigations.

Limitations

This study was limited by its small sample, single-centre design, convenience sampling, and reported six-month follow-up. Residual kidney function and middle-molecule clearance were not evaluated. Differences in vascular access, haemoglobin, and albumin may confound observed associations.

Conclusion

This prospective observational study demonstrated that inadequate dialysis adequacy (Kt/V <1.2) was associated with higher observed rates of cardiovascular complications, infections, and hospitalization among patients receiving maintenance haemodialysis. Although mortality was numerically higher in the inadequate-Kt/V group, the difference was not statistically significant. These findings highlight the importance of routine dialysis adequacy monitoring alongside comprehensive clinical assessment. Larger multicentre prospective studies are warranted to confirm these associations and clarify their implications for long-term patient outcomes.

Declarations

Ethics Approval: This study was approved by the Institutional Ethics Committee of Jawaharlal Nehru Medical College and Hospital (JLNMCH), Bhagalpur, Bihar, India.

Availability of data and materials: The datasets analysed during the current study are available from the corresponding author on reasonable request.

Conflict of interest: The authors declare no conflict of interest.

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