

ORIGINAL ARTICLE

Efficacy and Safety of Desidustat Versus Erythropoietin in Post Kidney Transplant Anaemia: A Prospective Observational Study

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ABSTRACT

Aim: Post-renal transplant anaemia significantly impacts patient outcomes and quality of life. The only option available until recently was erythropoietin (EPO) that requires intravenous or subcutaneous injection. New class of drugs that are hypoxia-inducible factor prolyl hydroxylase inhibitor (HIF-PHI) (desidustat) have become available and there is scarce data on their use in kidney transplant recipients (KTRs).

Methods: This was a prospective observational study which included 58 renal transplant recipients with anaemia (Hb < 10 g/dL) who were started on either oral HIF-PHI in the form of desidustat ($n = 30$) or EPO ($n = 28$) based on nephrologist discretion. Adult KTRs with a haemoglobin (Hb) level of less than 10 g/dL were included. Patients with acute graft dysfunction, bleeding and primary haematological diseases were excluded. Baseline clinical characteristics were recorded. Primary outcomes were change in Hb at 8 weeks in the two groups. Secondary outcomes included inflammatory markers (CRP, ESR), iron indices and safety.

Results: Both desidustat and erythropoietin groups showed significant improvement in Hb from baseline to 2 months (desidustat: 8.69 ± 0.86 to 9.89 ± 0.92 g/dL; EPO: 8.54 ± 0.73 to 9.55 ± 0.71 g/dL; $p > 0.05$). No significant differences were observed in inflammatory markers or iron indices. Both treatments were well-tolerated, with no reported adverse events.

Conclusion: Treatment with desidustat resulted in improvement in haemoglobin levels with acceptable tolerability over short-term follow-up similar to erythropoietin. The convenience of oral administration supports its potential role as a patient-centred option for anaemia management following kidney transplantation.

Pooja Barak and Smita Divyaveer contributed equally as first authors.

1 | Introduction

Anaemia is a frequently encountered complication among patients after renal transplantation, affecting a substantial proportion during the post-transplant period. Reports on the prevalence of anaemia in these patients vary widely, ranging from 20% to 51%, depending on the study. This variation is influenced by factors such as the definitions of anaemia and the time elapsed since transplantation [1, 2]. The prevalence of anaemia in post-transplant patients varies according to time since kidney transplantation. In the early post-transplant period, it can often be attributed to factors like surgical blood loss, reduced erythropoietin production due to allograft dysfunction, and the effects of immunosuppressive medications. Typically, anaemia resolves within 3–6 months in patients with well-functioning allografts [3]. However, 6–12 months post-transplant, other contributors such as iron deficiency, chronic inflammation, graft dysfunction, drugs, the influence of inflammatory markers, infections, and so forth, play a more prominent role in the persistence of anaemia [3]. Uncorrected anaemia not only reduces patients' quality of life but is also associated with cardiovascular complications [4], graft failure and mortality [5].

Effectively managing anaemia in post kidney transplant patients requires understanding its duration and causes. Despite optimisation of immunosuppressive therapy, treatment of infections and nutritional deficiencies, patients with chronic allograft dysfunction continue to have anaemia requiring erythropoietin similar to patients with anaemia of chronic disease in chronic kidney disease (CKD). While a new class of drugs namely hypoxia-inducible factor prolyl hydroxylase inhibitor (HIF-PHI) has been used to treat the anaemia in CKD, data on the use of this class of drugs in kidney transplant recipients (KTRs) is scarce. These drugs work by activating the hypoxia-inducible factor pathway, thereby promoting the production of endogenous erythropoietin. Studies conducted in other patient groups, such as those with chronic kidney disease (CKD), have shown that HIF-PHI can lower inflammatory markers like IL-6 and CRP and improve iron metabolism [6].

Not all HIF-PHIs are available equally across the globe. In India, desidustat, a hypoxia-inducible factor prolyl hydroxylase inhibitor is an available alternative treatment option for renal anaemia. Given its demonstrated efficacy in raising haemoglobin levels and reducing inflammation in other populations, desidustat offers a dual benefit: correcting anaemia while simultaneously addressing the underlying inflammatory burden that often complicates treatment. It is being used as an alternative to erythropoietin in the treatment of anaemia in KTRs. Therefore, we designed this observational study to evaluate the efficacy and safety of desidustat in the treatment of anaemia in kidney transplant recipients and to assess its impact on inflammatory markers in comparison to erythropoietin therapy.

2 | Materials and Methods

2.1 | Study Design and Population

This single-centre, prospective, observational pilot study was conducted at the outpatient department of the Post Graduate Institute of Medical Education and Research (PGIMER),

Chandigarh, India. The study (CTRI/2024/08/072458) was conducted between September 2023 and October 2024. Renal transplant recipients with anaemia (Hb < 10 g/dL) were screened. Patients with stable graft function defined as < 25% increase in serum creatinine and no change in immunosuppressive medication dosages in the prior 3 months were included. Patients with active bleeding, ongoing acute graft-on-chronic dysfunction, primary haematological disorders, presence of malignancies, pregnant or lactating individuals and those on dialysis were excluded. Patients with nutritional deficiencies were supplemented, and patients were reassessed after repletion of deficiencies for eligibility. Patients who developed severe infections requiring hospital admission or bleeding from any site during the study period were excluded from analysis as these factors can affect haemoglobin levels independently.

2.2 | Treatment of Anaemia

Eligible patients from the outpatient department of Nephrology at PGIMER, Chandigarh were enrolled. Patients started on either erythropoietin or desidustat, as determined by their primary care nephrologist, were assigned to erythropoietin and desidustat groups, respectively. The choice of treatment was up to the treating nephrologist, and several factors (cost of both drugs, prior EPO exposure, patient preference and availability of either drug etc.) are responsible for choosing erythropoietin over desidustat or vice versa. As the cost of desidustat is similar to erythropoietin in our country, hence financial constraints are unlikely to affect the choices. Moreover, all the recruited subjects were naïve to erythropoietin exposure. The protocol of dosage of erythropoietin (150 units/Kg/week, rounded off to the closest value 1000) and desidustat (100 mg thrice a week) and further tapering of dose is given in Figures S1 and S2. Clinical and laboratory data were recorded. Routine investigations for CKD patients with anaemia were documented, including complete blood count (CBC), peripheral smear, reticulocyte count, stool occult blood, serum iron studies, B12 levels and folate levels. Patients were enrolled into erythropoietin or desidustat groups and followed up for 2 months.

2.3 | Study Assessments

The patients were evaluated for medical history and laboratory investigations, including haemoglobin levels (Hb), serum iron, serum ferritin, total iron-binding capacity (TIBC) and inflammatory markers including erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) and levels of tacrolimus or cyclosporine. Primary outcome measured was changes in Hb levels at 8 weeks. Secondary outcomes focused on changes in inflammatory markers (CRP, ESR), iron indices, and cyclosporine or tacrolimus levels. Adverse events were recorded as minor if treated on an outdoor basis and major if they required admission to hospital.

2.4 | Sample Size and Statistical Analysis

This was a pilot observational study, and a feasibility sample size of 60 was decided. This study included 58 renal transplant

recipients diagnosed with anaemia, of whom 30 received desidustat and 28 received erythropoietin. The data were collected, and appropriate statistical analysis was performed using Epi Info version 7.2. Demographic and baseline characteristics are summarised using descriptive statistics. Categorical variables are summarised with frequency and percentage. Continuous variables are summarised with mean, standard deviation, and so forth. A *p* value of continuous variables was analysed using ANOVA (after checking the normal distribution of the data), and categorical data were compared using chi-square tests. Mann-Whitney *U* test was performed for inter-group comparisons. *p* < 0.05 was considered significant. Missing data were assessed with Little's MCAR test. Multiple imputation was used for MAR data, and sensitivity analyses confirmed consistent results. Analyses were conducted using Epi Info 7.2, with minimal impact on findings due to low missingness (<10%).

2.5 | Ethics Statement

This pilot study was reviewed and approved by the institutional ethics committee (approval number: IEC-INT/2023-SPL1024 A). The study was conducted in accordance with the ethical principles that have their origin in the Declaration of Helsinki and in accordance with the International Conference on Harmonization's Good Clinical Practice guidelines (ICH-GCP). All participants provided written and informed consent.

3 | Results

Total of 83 renal transplant recipients with anaemia were screened. Twenty patients were excluded for various reasons. All 63 patients completed 2 months of follow-up. However, during

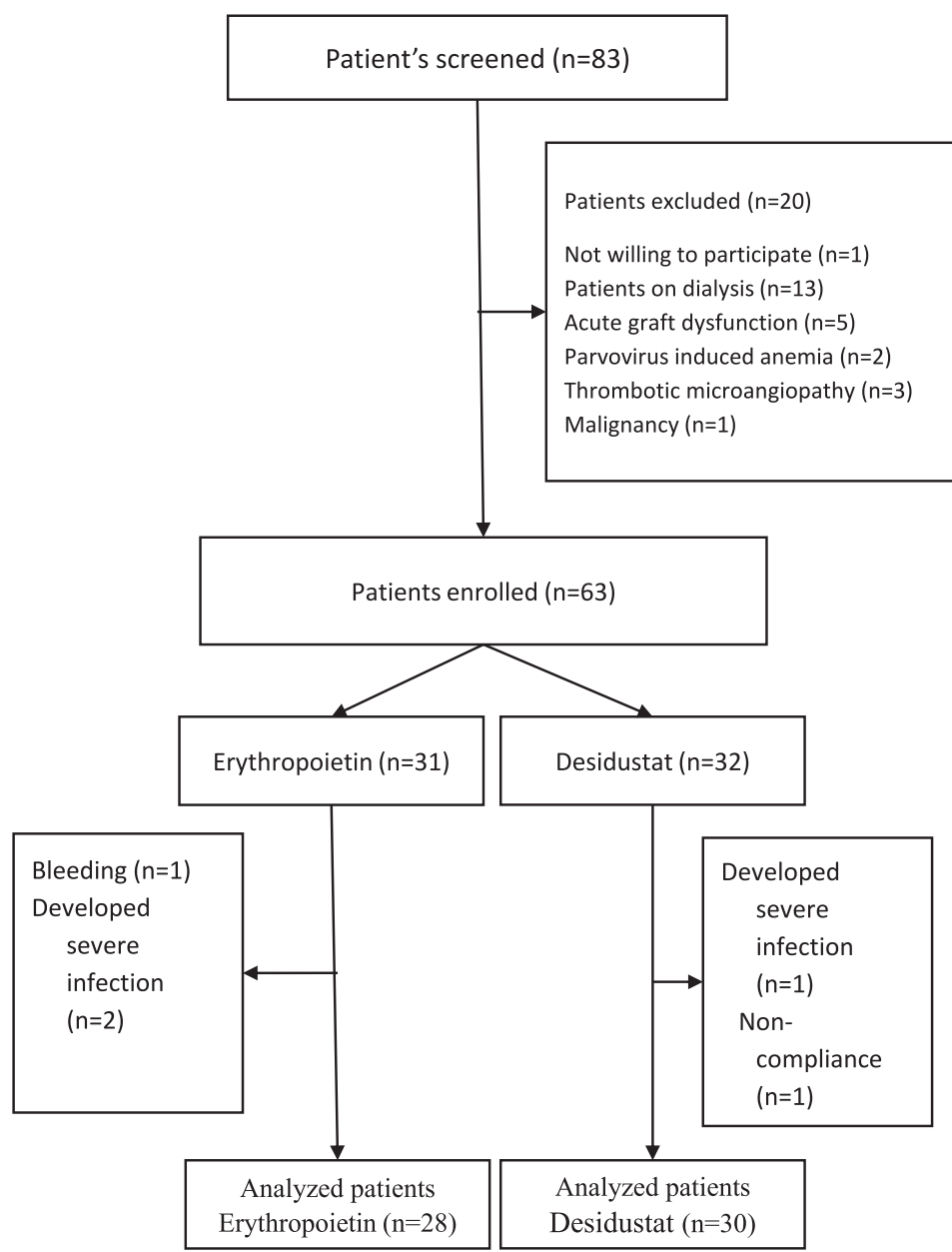


FIGURE 1 | Enrolment of study subjects.

the study period, three patients developed severe infection, one had massive gastrointestinal bleeding and one patient was non-compliant to medication for more than 2 weeks. These five patients were excluded from analysis. Data of 58 patients; 30 in desidustat group and 28 in erythropoietin group were included in analysis. The details of patient recruitment flow chart are shown in Figure 1. The baseline haemoglobin, iron indices and iron profile were similar in both the study groups. The baseline characteristics of study participants are shown in Table 1 below. The mean duration since time of transplantation was 4.01 ± 2.23 and 3.53 ± 1.98 years. The causes of chronic allograft dysfunction were chronic rejection ($n=21$), chronic calcineurin toxicity ($n=4$), disease recurrence ($n=4$) and BK Virus nephropathy ($n=1$) in the desidustat group. The etiologies of chronic graft dysfunction in the erythropoietin group were chronic rejection ($n=19$), chronic calcineurin toxicity ($n=3$), disease recurrence ($n=3$), non-specific chronicity ($n=2$) and non-recovery of AKI ($n=1$). Twenty-five patients and 22 patients were on triple immunosuppression in desidustat and erythropoietin groups respectively. Eleven patients among the entire study population were on dual immunosuppression for at least 3 months prior to enrolment (patients with change in immunosuppression within prior 3 months were excluded from the study). In these patients calcineurin inhibitors were stopped other patients in view of calcineurin toxicity or for stepping down immunosuppression for repeated infections. All patients were on anti-proliferative medication; 23 and 22 on mycophenolate and seven and six patients in each group on azathioprine in desidustat and erythropoietin groups, respectively.

3.1 | Change in Haemoglobin and Iron Studies in the Two Study Groups

Both groups demonstrated significant within-group increases in haemoglobin levels over 8 weeks. Desidustat group had improvement in Hb from 8.69 ± 0.86 to 9.89 ± 0.92 g/dL, and erythropoietin group had improvement in Hb from 8.54 ± 0.73 to 9.55 ± 0.71 g/dL. Median haemoglobin levels in both the groups are presented in the Table S1. No significant inter-group differences were observed (Figure 2). At baseline, the mean iron levels were 96.55 ± 27.13 µg/dL for desidustat group and 96.46 ± 27.57 µg/dL for erythropoietin group ($p=0.990$). By Week 8, the levels had slightly increased, but no significant inter-group differences were found ($p=0.59$). Similar trends were observed for total iron-binding capacity (TIBC) and transferrin saturation (Tsats), with no significant changes or group differences over 2 months. Mean changes and magnitude of difference in iron parameters in both the groups are presented in the Table S2.

3.2 | Inflammatory Markers

No significant changes were observed in CRP and ferritin between the groups over the study period (Table 2). Table S2 represents mean change and magnitude of difference in inflammatory markers between groups. ESR was significantly higher in the erythropoietin group on follow-up as compared to the Desidustat group.

TABLE 1 | Baseline characteristics of study participants in the desidustat and erythropoietin groups.

Parameter	Desidustat ($n=30$) (mean $\pm$ SD)	Erythropoietin ($n=28$) (mean $\pm$ SD)	<i>p</i>
Age (years)	49.7 ± 16.77	50.96 ± 16.68	0.775
Sex (male/ female)	16/14	19/9	0.195
Creatinine (mg/dL)	3.44 ± 1.06	3.09 ± 0.81	0.169
Haemoglobin (g/dL)	8.69 ± 0.86	8.54 ± 0.73	0.488
Iron (µg/dL)	96.55 ± 27.13	96.46 ± 27.57	0.990
TIBC (µg/dL)	283.39 ± 58.46	306.74 ± 59.54	0.137
Transferrin saturation (%)	33.38 ± 8.90	35.43 ± 8.65	0.377
MCV (fL)	88.30 ± 5.70	89.82 ± 6.57	0.349
MCH (pg)	29.13 ± 1.74	29.39 ± 1.77	0.575
MCHC (g/dL)	33.50 ± 1.17	33.29 ± 1.12	0.479
Vitamin B12 (pg/mL)	400.54 ± 111.51	394.25 ± 110.97	0.830
Folate (ng/ mL)	12.8 ± 4.83	12.45 ± 4.3	0.775
LDH (U/L)	185.45 ± 33.2	195.53 ± 32.74	0.250
Ferritin (ng/ mL)	316.8 ± 115.45	329.75 ± 121.18	0.679
CRP (mg/L)	4.31 ± 1.76	4.37 ± 1.94	0.911
ESR (mm/h)	23.59 ± 8.6	27.4 ± 8.34	0.094
AST (U/L)	25.17 ± 8.55	24.68 ± 9.4	0.837
ALT (U/L)	26.47 ± 8.96	25.68 ± 9.86	0.751
Calcium (mg/ dL)	9.52 ± 0.67	9.67 ± 0.53	0.350
Phosphate (mg/dL)	3.7 ± 0.61	3.48 ± 0.52	0.150
Vitamin D (ng/mL)	64.66 ± 20.21	65.02 ± 20.45	0.947
iPTH (pg/mL)	141.83 ± 17.78	138.35 ± 15.79	0.435

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; iPTH, intact parathyroid hormone; LDH, lactate dehydrogenase; TIBC, total iron-binding capacity.

3.3 | Cyclosporine and Tacrolimus Levels

In desidustat and erythropoietin groups 23 and 18 patients were on tacrolimus, respectively and two and four patients were on cyclosporine, respectively. At baseline, the mean tacrolimus levels were 6.10 ± 0.65 ng/mL in desidustat group and 6.02 ± 0.58 ng/mL in erythropoietin group ($p=0.657$).

At Week 8, these levels increased slightly (statistically insignificant) to 6.31 ± 0.69 and 6.35 ± 0.53 ng/mL, respectively ($p = 0.831$). Baseline cyclosporine levels were 83.5 ± 7.78 ng/mL in desidustat group and 79.5 ± 12.76 ng/mL in erythropoietin group ($p = 0.714$). At Week 8, the levels were 96.5 ± 4.95 and 99.5 ± 15.29 ng/mL, respectively, with no significant differences observed ($p = 0.810$).

3.4 | Adverse Events

Three patients developed severe infection in the form of urinary tract infection, dengue fever and pneumonia during the study period and one patient developed massive bleeding requiring blood transfusion due to diverticulosis. The patient who developed urinary tract infection has a prior history of multiple urinary tract infections due to bladder abnormality. No other adverse events, either minor or major, were reported in either treatment group during the study period. No patient reported any gastrointestinal intolerance to desidustat. One patient was non-compliant to all medication, not desidustat alone (excluded from analysis).

4 | Discussion

HIF-PHIs are emerging as an alternative to treat anaemia in CKD but there is scarce data on use of these agents in kidney transplant recipients (Table 3). Desidustat is approved in India and is widely available for use in patients with CKD, with similar cost and effectiveness to erythropoietin. It is used off label in renal transplant recipients and there is no data to the best of

our knowledge on use of desidustat in KTRs. Although this is an observational study, it has the largest sample size on use of desidustat in the transplant population to date. This study provides evidence for desidustat's significant impact on increasing haemoglobin levels post kidney transplant, establishing it as a viable and patient-friendly treatment option.

Desidustat is a novel therapeutic agent belonging to the HIF-PHI class, which replicates the body's hypoxic response [7]. HIF-PHIs not only increase endogenous erythropoietin production but also reduce hepcidin levels, enhancing iron mobilization [8]. These properties make HIF-PHIs particularly effective in treating inflammation-related anaemia, which is commonly observed in post-transplant patients. In contrast to ESAs, which act directly on erythroid progenitors to stimulate red blood cell production, HIF-PHIs provide the added advantage of addressing disrupted iron metabolism through hepcidin suppression [9]. Only one prior prospective randomised study in kidney transplant recipients has assessed HIF-PHI therapy for post-transplant anaemia, demonstrating the efficacy of roxadustat. However, the comparator group received iron alone, with no use of erythropoietin, and baseline anaemia was mild (mean haemoglobin 10.56 ± 0.44 g/dL) [10]. In contrast, our study compared desidustat with erythropoietin, the standard of care, in patients with more severe baseline anaemia (mean haemoglobin ~ 8.6 g/dL). We found similar potency of erythropoietin and desidustat in improving Hb in KTRs and in safety profile.

The effect of desidustat in our study is similar to a prior study by Provenzano et al. in CKD patients that demonstrated HIF-PHIs' effectiveness in stimulating erythropoiesis [11] with maintained stable iron indices (serum iron, TIBC and TSAT) throughout the study, with no significant differences observed. This corroborates with another study by Locatelli et al., which noted that short-term HIF-PHI therapy does not immediately alter iron parameters [12]. However, long-term data, such as that from Li et al., suggest that HIF-PHIs improve iron bioavailability through sustained hepcidin reduction [13]. Studies with longer follow-up are warranted to ascertain the effect of Desidustat on iron profile parameters.

The dual mechanism of improvement in iron metabolism and inflammation exerted by HIF-PHIs may offer significant benefits, particularly for individuals who do not respond adequately to traditional ESA therapy due to inflammatory conditions as reported with use of Vadadustat in CKD [14]. Coyne et al. reported similar findings, underscoring the anti-inflammatory effects and iron-modulating capabilities of HIF-PHIs, which are

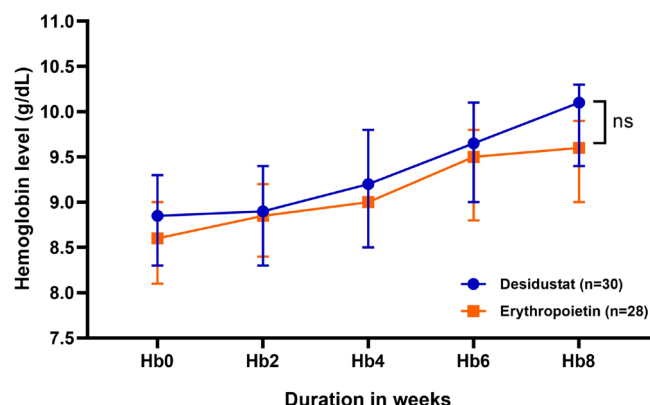


FIGURE 2 | Change in haemoglobin (Hb) in two groups. Hb0, Hb2, Hb4, Hb6 and Hb8 indicate Hb at Weeks 0, 2, 4, 6 and 8, respectively.

TABLE 2 | Comparison of inflammatory markers in the desidustat and erythropoietin groups at baseline and follow-up.

Inflammatory markers	Baseline			Follow-up (8 weeks)		
	Desidustat group	Erythropoietin group	p	Desidustat group	Erythropoietin group	p
CRP (mg/L)	4.31 ± 1.76	4.37 ± 1.94	0.911	4.12 ± 1.94	4.4 ± 1.35	0.528
ESR (mm/h)	23.59 ± 8.59	27.40 ± 8.34	0.094	24.36 ± 4.5	29.56 ± 7.69	0.002
Ferritin (ng/mL)	316.8 ± 115.45	329.75 ± 121.18	0.679	462.30 ± 119.8	497.57 ± 112.43	0.253

Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate.

TABLE 3 | Comparison of HIF-PHI agents: availability and data in kidney transplant recipients from across the world.

HIF-PHI agent	Approved countries till 2024	Data in KTRs	Study details	Study design	Main conclusion
Roxadustat	China, Japan, Chile, South Korea, European Union and others	Yes	RCT of 150 KTR ^a Retrospective study with 57 KTRs ^b	RCT and retrospective comparative cohort	Improved haemoglobin levels and iron utilisation in early post-transplant anaemia
Vadadustat ^c	USA, Japan, Australia, European Union and other countries	No	No published studies in KTRs	N/A	Effective in non-dialysis-dependent CKD patients with anaemia
Daprodustat ^d	USA, Japan	Yes	Study with 21 KTRs over 12 months	Observational study	Significantly increased haemoglobin levels; well-tolerated over 1 year
Molidustat ^e	Japan	No	No published studies in KTRs	N/A	Improved anaemia in CKD patients, especially in inflammation-driven states
Desidustat	India	Yes	Present study in KTR (no prior studies in KTRs)	Observational study with comparator arm with erythropoietin	Non-inferior to epoetin alfa in increasing haemoglobin levels

Abbreviations: HIF-PHI, hypoxia-inducible factor prolyl hydroxylase inhibitors; KTR, kidney transplant recipients.

^aKong W. et al. *Kidney International Reports* 9, no. 6 (2024): 1705–1717.

^bLi H. et al. *Annals of Translational Medicine* 10, no. 24 (2022): 1360.

^cXiong L. et al. *Frontiers in Pharmacology* 12 (2022): 795214.

^dMachida Y. et al. *Transplantation Proceedings* 56, no. 3 (2024): 534–539.

^eYamamoto H. et al. *American Journal of Nephrology* 52, no. 10–11 (2021): 871–883.

particularly relevant in the post-transplant setting [15]. Some HIF-PHIs such as roxadustat [16] and molidustat [17] have been reported to have improved anaemia, especially in states with increased inflammation characterised by raised CRP [18]. But a similar effect was not found with daprodustat [19]. In our study, the inflammatory markers (CRP and ESR) showed no significant inter-group differences, further supporting the safety of desidustat with regard to these inflammatory markers.

HIF-PHIs have had several safety concerns because of which they are not globally used as an alternative to erythropoietin. The major concerns have been with regards to cardiovascular safety, carcinogenic concerns, risk of increased thrombosis [20] and risk of infections [21]. The adverse effects do not seem to be uniform across all HIF-PHIs and hence cannot be considered a class effect. Some agents have been approved in various countries for use in CKD patients, for example, daprodustat and vadadustat have been approved for use in the United States. Desidustat was developed in India and has been approved for use in CKD patients with anaemia since 2022 [22]. Available literature on desidustat indicates that it is devoid of major adverse effects unlike other drugs of this class. It is being used off label in transplant due to its availability and ease of administration. We found that both desidustat and EPO are well-tolerated, with no significant interactions with immunosuppressive agents, such as tacrolimus and cyclosporine. There were two severe infection episodes but it cannot be ascertained if desidustat was contributory. This aligns with Miki et al. findings, which demonstrated that roxadustat, another HIF-PHI, maintains a strong safety profile in post-transplant populations [23]. The prospective randomised controlled trial by Zhang et al. evaluated roxadustat against iron alone in patients with mild anaemia (mean baseline Hb ~10.5 g/dL) [24], while retrospective analyses compared roxadustat with no treatment or iron supplementation [25]. Similarly, daprodustat has only been evaluated in a single-arm observational study in KTRs [26]. In contrast, our study directly compares desidustat with erythropoietin, the standard of care, thereby providing clinically meaningful comparative effectiveness data. Data on drug-drug interactions between HIF-PHIs and calcineurin inhibitors remain limited. Our study adds novel safety data showing no significant interaction with tacrolimus or cyclosporine levels, no rejection episodes and no signal for excess inflammation, complementing prior safety observations with roxadustat in KTRs [26] and extending them to desidustat.

Our study lays down the first report of efficacy and safety of desidustat in KTRs. However, there are some limitations. The 8-week endpoint was chosen to assess early response and short-term safety in this pilot study. We acknowledge that steady-state Hb responses typically require longer follow-up and that effects may be underestimated. Although we did not find any rejection episodes during the study, we cannot ascertain the effect of desidustat on the pharmacokinetics of anti-proliferative agents as therapeutic level monitoring is not routinely done for these agents for all patients. We did not perform a comprehensive analysis with regard to the anti-inflammatory effect of desidustat on markers such as interleukin 6 and hepcidin in our study population. The follow-up duration in our study is relatively short and the sample size is small; hence, larger studies with longer follow-up are warranted to study the effect of desidustat on long-term outcomes.

5 | Conclusion

Desidustat is as efficacious as erythropoietin in the treatment of anaemia in post-renal transplant patients. It has a similar effect on iron profile and inflammatory parameters as compared to erythropoietin. Adverse events were similar between the two groups. Due to its ease of administration, desidustat can be a patient-centred option in clinical practice for the treatment of anaemia post kidney transplant. Future research should explore its long-term effects, cost-effectiveness and broader therapeutic potential.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Protocol for the dosage of desidustat and further tapering of the dose in KTRs. **Figure S2:** Flow diagram representation of protocol for erythropoietin dosage in the KTRs. **Table S1:** Median haemoglobin levels in the erythropoietin and desidustat group at various time points. **Table S2:** Mean change in parameters from baseline to 2 months follow-up in the desidustat and erythropoietin groups.