

Clinical Outcomes and Complications after Pediatric Kidney Transplantation: A Single-Centre Retrospective Cohort

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ABSTRACT

Background: Contemporary outcome data from pediatric kidney transplant programmed in resource-constrained settings remain limited. We described recipient characteristics, post-transplant complications, and status at last follow-up in a single-centre cohort.

Methods: We performed a retrospective study of 50 kidney transplant recipients aged 18 years or younger at transplantation between 2011 and 2025. Clinical variables were analyzed descriptively. Continuous variables were summarized as mean and standard deviation, and categorical variables as frequency and percentage.

Results: Recipients aged 11–14 years comprised 14 (28%) and those aged 15–18 years 36 (72%); 37 (74%) were male. Donors were mothers in 30 (60%), fathers in 14 (28%), and deceased donors in 6 (12%). Induction was not given in 31 (62%), while 12 (24%) received basiliximab and 7 (14%) antithymocyte globulin. Among the 31 recipients without induction, 23 (74.2%) had rejection: chronic antibody-mediated rejection in 11 (35.48%), acute antibody-mediated rejection in 6 (19.4%), and acute cellular rejection in 6 (19.4%). Calcineurin-inhibitor toxicity occurred in 26%, rejection in 46%, recurrence in 10%, cytomegalovirus infection in 12%, and post-transplant diabetes mellitus in 20%. At last follow-up, 34 (68%) recipients were alive, 10 (20%) were alive with a failing graft, and 6 (12%) had died.

Conclusion: Post-transplant complications were frequent in this pediatric cohort. The findings emphasize the higher rejection burden observed among recipients without induction and the importance of careful calcineurin-inhibitor monitoring to reduce toxicity and infection.

Abbreviations

ABMR	: Antibody-Mediated Rejection
ACR	: Acute Cellular Rejection
ATG	: Antithymocyte Globulin
BK	: Polyomavirus
CI	: Confidence Interval
CNI	: Calcineurin Inhibitor
CMV	: Cytomegalovirus
DGF	: Delayed Graft Function
IGF	: Immediate Graft Function
IQR	: Interquartile Range
PTDM	: Post-Transplant Diabetes Mellitus
SGF	: Slow Graft Function

TMA	Thrombotic Microangiopathy
UTI	Urinary Tract Infection

Keywords: Pediatric Kidney Transplantation, Graft Rejection, Calcineurin Inhibitors, Infection, Graft Failure, Tacrolimus

Introduction

Kidney transplantation is the preferred kidney-replacement therapy for children with kidney failure because it offers advantages in survival, growth, neurodevelopment, and health-related quality of life compared with maintenance dialysis [1]. Improvements in surgery, immunosuppression, infection prevention, and multidisciplinary follow-up have produced excellent medium-term outcomes; nevertheless, a child who receives a graft must often preserve kidney function across many decades [1,2].

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The post-transplant course is therefore shaped by competing risks. Inadequate immunosuppression or poor drug exposure can contribute to rejection, whereas excessive exposure increases the risks of nephrotoxicity, infection, and metabolic complications. Disease recurrence and the transition from pediatric to adult care add further threats to graft longevity [1,3]. International guidance recommends induction as part of initial immunosuppression for most kidney transplant recipients and regular monitoring of calcineurin-inhibitor concentrations, but the strength of supporting evidence and the balance of benefit and harm vary with immunological risk and local practice [3].

Published Indian pediatric transplant data remain concentrated in a relatively small number of centres. A national systematic review estimated one-, five-, and ten-year patient survival of 96%, 90%, and 75%, respectively, and corresponding graft survival of 93%, 83%, and 66%; infections were prominent contributors to adverse outcomes [4]. Centre-level reports are important because donor sources, access to induction agents and drug monitoring, infectious exposures, and continuity of follow-up differ substantially across settings [4,5].

This study aimed to describe the demographic and transplant characteristics, graft function, rejection, CNI toxicity, disease recurrence, infections, PTDM, graft status, and vital status of pediatric kidney transplant recipients managed at a single tertiary centre. A secondary, exploratory objective was to compare documented rejection across induction-therapy groups without making causal inferences.

Materials and Methods

Study Design and Setting

This was a single-centre retrospective, cross-sectional study based on review of clinical records. The study included kidney transplants performed from 2011 through 2025, with recorded clinical status updated to June 2025. Reporting was structured with reference to the Strengthening the Reporting of Observational Studies in Epidemiology recommendations [6].

Study Centre and Location: Tertiary Care Center, Telangana Participants

All available recipients aged 18 years or younger at the time of kidney transplantation were included. Both living-related and deceased-donor transplants were eligible. The supplied dataset contained 50 unique recipients and no explicit exclusions. Because the dataset represented the available centre cohort rather than a sampled population, no prospective sample-size calculation was performed.

Variables and Outcome Definitions

Variables abstracted from the source dataset were recipient and donor age and sex, primary kidney disease, transplant date and donor type, induction therapy, early graft-function category, tacrolimus metabolizer category recorded by the centre, discharge serum creatinine, donor-specific antibody testing, CNI toxicity, disease recurrence, non-CMV infection, rejection, CMV infection, tacrolimus concentrations at selected events, immunosuppressive regimen changes, latest serum creatinine, graft status, vital status, and PTDM.

Events were classified according to the diagnoses recorded in the

clinical dataset. Rejection was grouped as acute ABMR, chronic ABMR, or ACR. CNI toxicity was grouped as acute toxicity, chronic toxicity, or tacrolimus-associated TMA. A recipient was counted once for each patient-level outcome even when multiple infection events were recorded. The dataset did not provide uniform biopsy criteria, Banff grades, microbiological definitions, CMV syndrome-versus-disease classification, glycaemic criteria for PTDM, tacrolimus sampling time, assay method, or the operational method used to assign the metabolizer category. These variables were therefore treated as clinician-recorded outcomes rather than independently adjudicated endpoints.

Statistical Analysis

Continuous variables were summarized as mean and standard deviation. Categorical variables were reported as frequency and percentage. Group comparisons used the independent-samples t test or analysis of variance for normally distributed continuous variables, the Mann–Whitney U test for non-normally distributed variables, and Fisher’s exact test for categorical variables, as appropriate. A two-sided p value below 0.05 was considered statistically significant.

Results

Cohort and Transplant Characteristics

All 50 recipients in the source cohort were included. Median follow-up to June 2025 was 94.3 months (IQR 26.3–145.7; range 0.3–166.7). Mean recipient age was 15.94±2.02 years and median age was 16.5 years; 37 recipients (74%) were male. Mean donor age was 39.32±8.66 years. Forty-four grafts (88%) were from living-related donors, including 30 mothers and 14 fathers; six (12%) were from deceased donors. Primary kidney diseases were heterogeneous, with presumed chronic interstitial nephritis, including cases labelled with vesicoureteral reflux or congenital anomalies of the kidney and urinary tract, forming the largest group. Detailed baseline characteristics are shown in Table 1.

Table 1: Baseline Recipient, Donor, and Transplant Characteristics (N=50).

Characteristic	Value
Recipient age, years, mean±SD	15.94±2.02
Recipient age 11–14 years	14 (28%)
Recipient age 15–18 years	36 (72%)
Male recipient sex	37 (74%)
Donor age, years, mean±SD	39.32±8.66
Female donor sex	33 (66%)
Living-related transplant	44 (88%)
Deceased-donor transplant	6 (12%)
Mother donor	30 (60%)
Father donor	14 (28%)
No induction	31 (62%)
Basiliximab induction	12 (24%)
Antithymocyte globulin induction	7 (14%)
Immediate graft function	35 (70%)
Slow graft function	9 (18%)

Delayed graft function	6 (12%)
Discharge creatinine, mg/dL, mean±SD	0.94±0.25
Follow-up, months, median (IQR)	94.3 (26.3–145.7)

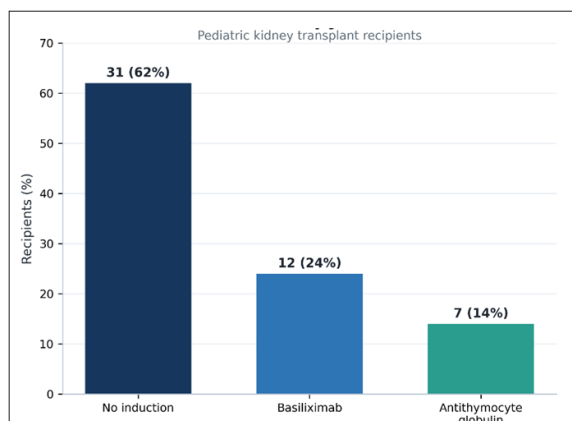


Figure 1: Induction Therapy Distribution

Among 50 paediatric kidney transplant recipients, 31 (62%) did not receive induction therapy, 12 (24%) received basiliximab, and 7 (14%) received ant thymocyte globulin. Thus, most recipients underwent transplantation without induction.

Rejection, Toxicity, Recurrence, and Infection

Rejection was documented in 23 recipients (46%). Among the 31 recipients who did not receive induction, 23 (74.2%) experienced rejection: chronic ABMR in 11 (35.48%), acute ABMR in 6 (19.4%), and ACR in 6 (19.4%). CNI toxicity occurred in 13 recipients (26%), and disease recurrence was documented in 5 (10%).

The recorded infections included UTI, lower respiratory tract infection, tuberculosis, BK virus, coronavirus disease 2019, dengue, varicella zoster, epididymo-orchitis, and gluteal abscess. CMV infection was documented in six recipients (12%).

Table 2: Major Post-Transplant Complications.

Outcome	n (%)
Any rejection	23 (46)
Chronic antibody-mediated rejection among recipients without induction	11 (35.48)
Acute antibody-mediated rejection among recipients without induction	6 (19.4)
Acute cellular rejection among recipients without induction	6 (19.4)
Any calcineurin-inhibitor toxicity	13 (26)
Cytomegalovirus infection	6 (12)
Disease recurrence/related pathology	5 (10)
Post-transplant diabetes mellitus	10 (20)

Timing of Recorded Complications

The recorded timing of complications varied widely. Acute CNI toxicity occurred at a mean of 0.88 months after transplant, whereas chronic CNI toxicity occurred at a mean of 58.33 months. Mean times to acute ABMR, chronic ABMR, and ACR were 25.33, 53.73, and 36.17 months, respectively. These means describe only recipients who experienced the event and should

not be interpreted as cumulative-incidence estimates.

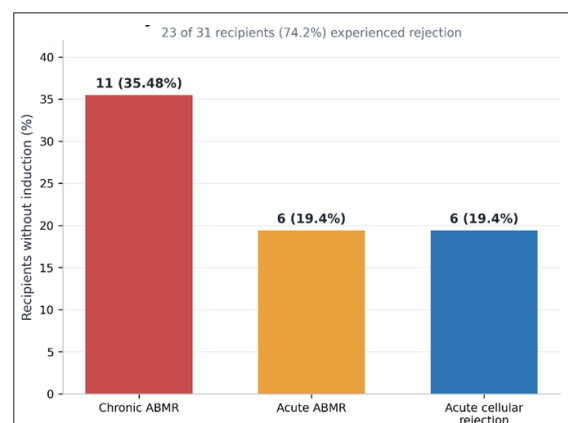


Figure 2: Rejection Pattern Without Induction

Among the 31 recipients who did not receive induction therapy, 23 (74.2%) developed rejection. Chronic antibody-mediated rejection was reported in 11 (35.48%), acute antibody-mediated rejection in 6 (19.4%), and acute cellular rejection in 6 (19.4%). Chronic antibody-mediated rejection was the most frequently reported subtype.

Table 3: Timing of Selected Documented Complications

Complication	Mean time after transplant, months
Acute calcineurin-inhibitor toxicity	0.88
Chronic calcineurin-inhibitor toxicity	58.33
Tacrolimus-associated thrombotic microangiopathy	0
Acute antibody-mediated rejection	25.33
Chronic antibody-mediated rejection	53.73
Acute cellular rejection	36.17
Focal segmental glomerulosclerosis recurrence	26
IgA nephropathy recurrence	92.67
Oxalosis	7

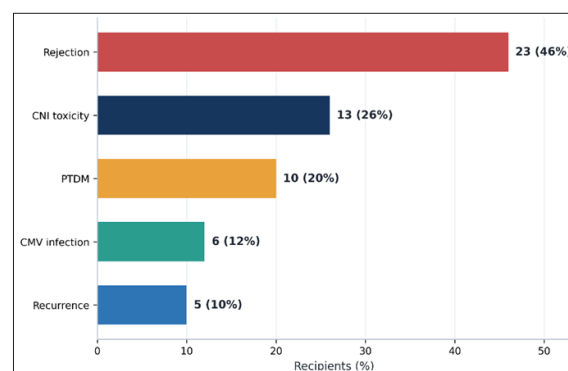


Figure 3: Major Post-Transplant Complications

Rejection was the most frequent complication, occurring in 23 recipients (46%). Calcineurin-inhibitor toxicity occurred in 13 (26%), post-transplant diabetes mellitus in 10 (20%), cytomegalovirus infection in 6 (12%), and disease recurrence in 5 (10%). These findings demonstrate the combined alloimmune, infectious, toxic, and metabolic burden after transplantation.

Induction Therapy and Rejection

Induction therapy was not administered to 31 recipients (62%); basiliximab was given to 12 (24%) and ATG to 7 (14%). Among the 31 recipients without induction, 23 (74.2%) had rejection. The reported rejection pattern comprised chronic ABMR in 11 (35.48%), acute ABMR in 6 (19.4%), and ACR in 6 (19.4%). This observation emphasizes the rejection burden in recipients managed without induction.

Table 4: Rejection Findings Among Recipients Without Induction

Finding	n (%)
Recipients without induction	31 (62)
Rejection among recipients without induction	23 (74.2)
Chronic antibody-mediated rejection	11 (35.48)
Acute antibody-mediated rejection	6 (19.4)
Acute cellular rejection	6 (19.4)

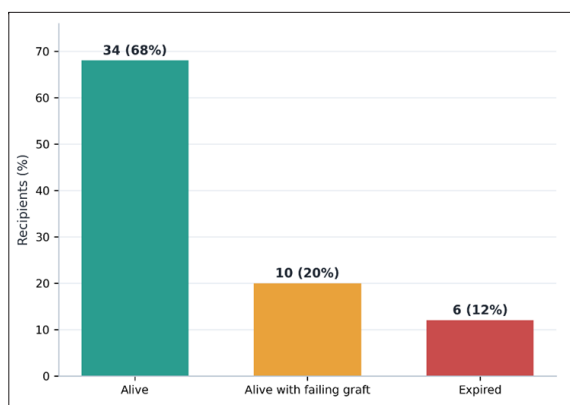


Figure 4: Clinical Status at Last Follow-Up

At the last recorded follow-up, 34 recipients (68%) were alive, 10 (20%) were alive with a failing graft, and 6 (12%) had died. Although most recipients remained alive, one-fifth had evidence of significant graft dysfunction.

Tacrolimus Concentrations

The mean tacrolimus level was 13 ng/mL at the time of CNI toxicity, 8.77 ng/mL at infection, and 3.22 ng/mL at rejection. These findings illustrate the narrow therapeutic range of tacrolimus and reinforce the importance of regular therapeutic drug monitoring to balance rejection prevention against toxicity and infection.

Graft and Patient Status

At last follow-up, 34 recipients (68%) were alive, 10 (20%) were alive with a failing graft, and 6 (12%) had died. The mean duration from transplantation to graft failure was 63.45 months, while the mean duration from transplantation to death was 69.33 months. PTDM was documented in 10 recipients (20%).

Table 5: Patient and Graft Status at Last Recorded Follow-Up

Status at last follow-up	n (%)
Alive	34 (68)
Alive with failing graft	10 (20)

Death	6 (12)
Mean duration to graft failure	63.45 months
Mean duration to death	69.33 months

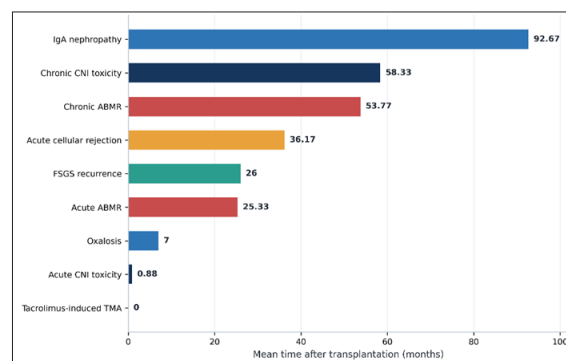


Figure 5: Timing of Post-Transplant Complications

Acute CNI toxicity developed early, at a mean of 0.88 months, while tacrolimus-induced thrombotic microangiopathy was reported in the immediate post-transplant period. Acute antibody-mediated rejection occurred at a mean of 25.33 months and acute cellular rejection at 36.17 months. Chronic CNI toxicity and chronic antibody-mediated rejection appeared later, at 58.33 and 53.77 months, respectively. IgA nephropathy recurrence was the latest event, occurring at a mean of 92.67 months

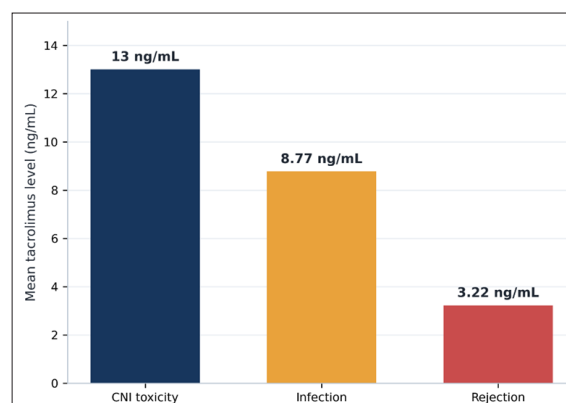


Figure 6: Tacrolimus Levels at Clinical Events

The mean tacrolimus level was highest during cni toxicity at 13 ng/ml, followed by infection at 8.77 ng/ml. The lowest mean level was recorded during rejection at 3.22 ng/ml. This pattern emphasizes the narrow therapeutic range of tacrolimus and the need to balance excessive exposure, which may contribute to toxicity and infection, against inadequate exposure, which may increase rejection risk.

Discussion

In this 14-year single-centre cohort of 50 pediatric kidney transplant recipients, rejection, CNI toxicity, infection, disease recurrence, graft dysfunction, and metabolic complications represented important post-transplant morbidity. Rejection occurred in 46% of the cohort, CNI toxicity in 26%, disease recurrence in 10%, CMV infection in 12%, and PTDM in 20%. At last follow-up, 68% of recipients were alive, 20% were alive with a failing graft, and 12% had died.

The 46% cumulative rejection proportion is higher than the pooled acute rejection estimate of 23% reported in an Indian

systematic review [4]. The estimates are not directly comparable. Our outcome combined acute ABMR, chronic ABMR, and ACR accumulated over as long as 13.9 years, whereas pooled reports varied in definitions and follow-up. Chronic ABMR accounted for almost half of the rejection diagnoses in this cohort, underlining the importance of long-term surveillance for alloimmune injury, adherence, donor-specific antibodies, and adequate immunosuppressive exposure. Contemporary literature also emphasizes that tacrolimus inpatient variability and time outside the therapeutic range may be more informative than isolated troughs [7].

A central observation was the high rejection burden among recipients who did not receive induction. Of the 31 recipients without induction, 23 (74.2%) developed rejection, including chronic ABMR in 11, acute ABMR in 6, and ACR in 6. Induction therapy reduces early alloimmune activation and is recommended as part of initial immunosuppression in most kidney transplant recipients [3]. Pediatric retrospective data have also examined ATG, basiliximab, and no-induction strategies, although the balance between rejection prevention and infectious or haematological complications must be individualized [8]. The present findings support careful immunological risk assessment and appropriate use of induction therapy.

The event-associated tacrolimus concentrations illustrate the clinical tension between underexposure and overexposure. The mean tacrolimus level was 13 ng/mL at toxicity, 8.77 ng/mL at infection, and 3.22 ng/mL at rejection. This pattern is clinically consistent with the recognized narrow therapeutic index of tacrolimus and guideline recommendations for therapeutic drug monitoring [3]. Careful dose adjustment and longitudinal trough monitoring are essential to reduce toxicity and infection while maintaining adequate rejection prophylaxis.

Infection was also prominent. Half of recipients had at least one non-CMV infection, with UTI, respiratory infection, tuberculosis, and BK virus recurring in the dataset; CMV infection was recorded in a further 12%. Indian transplant literature has identified infection as an important contributor to death and graft loss, reflecting local pathogen exposure and the challenge of balancing immunosuppression [4,5]. CMV remains a major pediatric transplant pathogen, and donor-recipient serostatus, prophylaxis, induction regimen, and rejection treatment influence risk [9]. The present dataset did not contain those details, so comparisons with other cohorts should remain descriptive.

PTDM was recorded in 20% of recipients. Pediatric reports have shown wide variation depending on screening intensity, diagnostic criteria, follow-up, and immunosuppressive regimen [10]. The absence of glucose, glycated haemoglobin, body-mass index, family history, and steroid-exposure data prevented evaluation of risk factors. Nevertheless, the observed burden supports routine metabolic surveillance beyond the immediate post-transplant period.

The cohort was dominated by adolescent male recipients and living-related transplantation, with mothers providing most living-donor grafts. This pattern resembles broader Indian experience, where living donation predominates and male recipients are overrepresented [4]. It also highlights the need

to interpret centre outcomes within the realities of donor availability and access to pediatric transplant services. The study contributes granular long-term complication data from a setting underrepresented in large registries, while also demonstrating why standardized prospective data capture is essential.

Strengths and Limitations

The principal strengths are inclusion of all available centre cases across 14 years and simultaneous description of alloimmune, infectious, toxic, recurrent-disease, metabolic, graft, and patient outcomes.

The study is limited by its retrospective single-centre design, small sample, absence of a contemporaneous comparator, and major differences in follow-up across treatment eras. Diagnoses were not independently adjudicated and several definitions were unavailable. Causes and exact dates of death, biopsy details, donor-specific antibody timing, CMV serostatus and prophylaxis, BK viral load, treatment of rejection, medication doses, adherence, anthropometry, and complete serial kidney-function data were not supplied. The tacrolimus values were sparse event-associated measurements rather than longitudinal exposure. The metabolizer category lacked a documented operational definition. Competing risks and losses to follow-up could not be fully evaluated. For these reasons, no causal conclusions should be drawn from induction-group or drug-level comparisons, and survival probabilities were not estimated.

Conclusion

Pediatric kidney transplantation at this centre was predominantly living-related and involved mainly adolescent recipients. Rejection, infection, CNI toxicity, disease recurrence, PTDM, and graft dysfunction were frequent. The high rejection burden among recipients without induction emphasizes the importance of appropriate induction therapy after individual immunological risk assessment. Higher tacrolimus levels at toxicity and infection and lower levels at rejection reinforce the need for careful therapeutic drug monitoring. Prospective studies with standardized definitions and longer follow-up are needed to validate these findings.

Recommendations

Establish a prospective pediatric transplant registry with standardized Banff rejection categories, infection definitions, graft-failure dates, causes of death, and transition-to-adult-care outcomes.

Record tacrolimus dose, true trough timing, assay, target range, concentration-to-dose ratio, and inpatient variability rather than relying on isolated event values.

Use risk-adjusted time-to-event methods to evaluate induction strategies and other treatment changes across eras.

Maintain structured surveillance for urinary and respiratory infection, tuberculosis, BK virus, CMV, glucose abnormalities, and recurrent kidney disease.

Declarations

Ethics Approval and Consent to Participate: Ethics approval has been taken from EIC. Consent waiver as it's a retrospective study.

Consent for publication: by all authors

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Author Contributions

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Project administration: Swarnalatha G

Visualization: Saahiti Sunkara, Swarnalatha G

Writing – original draft: Saahiti Sunkara, Swarnalatha G

Writing – review and editing: All authors

Declarations

Consent waiver as it was a retrospective study

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