Zhang *et al.*
European Journal of Medical Research (2025) 30:167
https://doi.org/10.1186/s40001-025-02422-9

European Journal of Medical Research

RESEARCH

Open Access

A comparative study of clinical outcomes and risk factors of tuberculosis in kidney transplant recipients from deceased donors

Hedong Zhang[1,2], Mingda Zhong[1,2], Shanbiao Hu[1,2], Liang Tan[1,2], Longkai Peng[1,2], Xubiao Xie[1,2] and Gongbin Lan[1,2*]

Abstract

Objective To investigate the clinical characteristics, diagnosis and treatment of tuberculosis infection after deceased donor kidney transplantation and to analyze the risk factors and prognosis of tuberculosis infection through a paired case–control study.

Methods This study investigated 31 kidney transplant recipients who developed tuberculosis among 2185 total recipients during 2012–2021. We employed a 1:1 paired case–control design, utilizing 31 patients who received kidneys from the same donor as the controls. The study analyzed clinical presentation, diagnosis, treatment, risk factors, and prognosis.

Results This study identified a 1.4% incidence of tuberculosis (TB) infection (31/2185) in kidney transplant recipients. The median onset was 10.8 months post-transplant (range: 5–24 months), with 51.6% occurring within the first year. Anti-TB therapy achieved cure in 30 patients, but one died and three experienced kidney transplant dysfunctions. While overall patient survival was not statistically different between groups, kidney graft survival was significantly lower in the TB group ($p=0.042$). While kidney function was initially similar, the TB group experienced significant declines in creatinine and GFR at 3, 6, and 12 months post-treatment ($p<0.05$). Multivariate analysis identified diabetes mellitus ($p=0.005$) and hepatitis ($p=0.027$) as independent risk factors for post-transplant TB infection.

Conclusion Over half of the tuberculosis cases (51.6%) occurred within the first year post-transplant, highlighting the need for heightened vigilance during this early period. While standard anti-TB therapy achieved good overall patient survival, it takes a toll on kidney function which underscores the importance of close kidney function monitoring and delicate immunosuppressant management during TB treatment. Diabetes mellitus and hepatitis were identified as independent risk factors for post-transplant TB infection. Prophylaxis measures should be considered for these high-risk patients during early time post-transplant.

Keywords Kidney transplantation, Tuberculosis, Tuberculosis infection, Risk factor analysis

Introduction

Tuberculosis is a highly contagious disease and is one of the most common causes of death from independent infection after SARS-coronavirus type 2 infection [1]. Compared to the national average, Hunan Province, where our transplantation center is located, has a higher TB burden. In 2018, the annual incidence of

*Correspondence:
Gongbin Lan
langongbin@csu.edu.cn
[1] Department of Kidney Transplantation, The Second Xiangya Hospital of Central South University, Changsha 410011, Hunan, China
[2] Clinical Research Center for Organ Transplantation in Hunan Province, Changsha, China

TB in Hunan Province was 76.9 per 100,000 population [2], compared with a national incidence of 61 per 100,000 in China [3]. The World Health Organization (WHO) estimated the global annual TB incidence to be 132 per 100,000 population in 2018 [4]. HIV patients, organ transplant patients, patients with chronic kidney failure requiring long-term hemodialysis, and patients using tumor necrosis factor (TNF)-receptor blockers are considered to be at high risk for TB infection [5]. In the same region, solid organ transplant recipients face a 36–74 times greater risk of contracting TB compared to the general population, due to long-term use of immunosuppressive therapy [6].

Additionally, observational studies in countries with high TB prevalence [4–6] have linked post-transplant TB to underlying chronic hepatitis (particularly chronic HCV), immunosuppressive regimens, and concurrent infections such as cytomegalovirus. TB treatment in solid organ transplant recipients is highly challenging due to severe drug interactions between anti-TB medications and immunosuppressants. The risk of graft loss, primarily from acute rejection, is significantly elevated, and mortality rates can reach as high as 40%. However, most studies on post-renal TB primarily focus on incidence, diagnosis, and treatment with limited research on risk factors. To address this gap, we conducted a comparative study of 31 TB patients with deceased donor (DD) kidneys and 31 matched controls from the same donor. By controlling for donor-transmitted TB, this study provides a foundation for improving TB prevention and diagnosis strategies.

Methods

Organ donation classification and procedures

Organ donation and transplantation processes adhere strictly to Chinese regulations governing organ donation after death. The donors are categorized and organs allocated according to these national guidelines. This study was approved by the Ethics Committee of Second Xiangya Hospital, Central South University, in accordance with the requirements of the Declaration of Helsinki.

Date collection

From January 1, 2012 to December 31, 2021, a total of 2185 DD donor kidney transplantations were performed in the Kidney Transplantation Department of the Second Xiangya Hospital of Central South University. Active TB is a contraindication to renal transplantation and candidates with active TB are excluded before transplantation. 31 cases of them were diagnosed with tuberculosis after surgery. A 1:1 matched case–control study was conducted comparing 31 tuberculosis patients with 31 control recipients from the same donor. The specific screening process was shown in Fig. 1.

Clinical data, including age, sex, BMI, pre-transplant renal replacement therapy type and duration, primary kidney disease, immunosuppressive regimen, comorbidities, and postoperative complications were collected for both case and control groups. For the case group (patients who developed TB post-transplant), data on TB treatment regimen, post-treatment outcomes, and post-treatment creatinine were also collected. All data were obtained from the China Human Organ Allocation and Sharing computer system (COTRS), China Kidney Transplant Scientific Registration system (CSRKT)

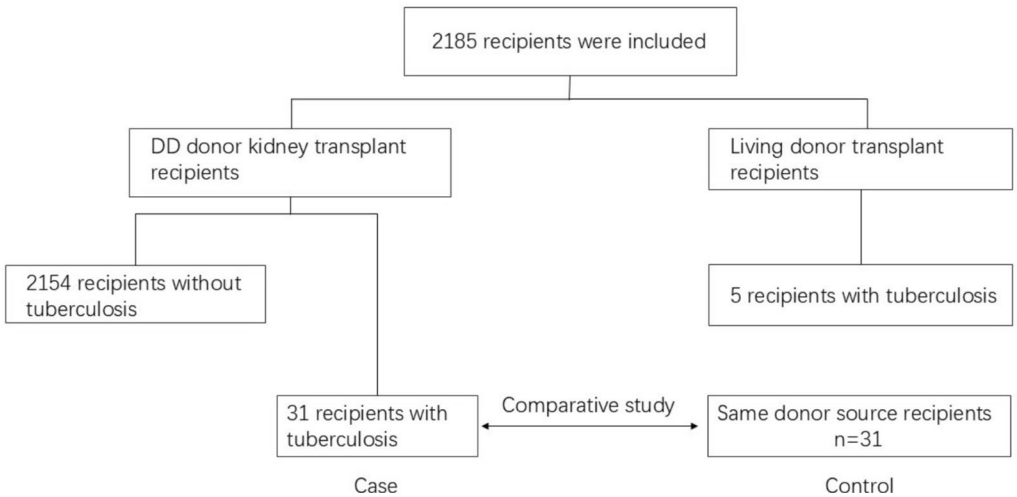

Fig. 1 Study design

and the electronic medical record system of the Second Xiangya Hospital of Central South University.

Inclusion/exclusion criteria for the experimental group

Inclusion criteria

1. Kidney transplant recipients who received deceased donor renal transplantation in the Second Xiangya Hospital of Central South University from January 1, 2012 to December 31, 2021;
2. Recipients diagnosed with tuberculosis after transplantation and receiving regular anti-tuberculosis therapy;
3. Tuberculosis cases diagnosed post-transplantation where the other kidney recipient from the same donor remained disease-free.

Exclusion criteria

1. Patients were diagnosed with tuberculosis after surgery but lost follow-up during anti-tuberculosis treatment;
2. 2. Donor-derived TB.

Induction and maintenance of immunosuppression

The induction method of kidney transplant recipients is routinely treated with Basiliximab or anti-human T lymphocyte rabbit immunoglobulin (ATG). All renal transplant recipients were given 1 g oral induction therapy of Mycophenolate Mofetil (MMF) 30 min before transplantation. Basiliximab was administered as a single 20 mg dose 2 h prior to transplantation, followed by a second 20 mg dose on the fourth postoperative day. ATG was administered intraoperatively and postoperatively at 25 mg per day for 1–3 days depending on the recipients' immunological risk. All recipients received intravenous methylprednisolone impulse therapy (500 mg each dose, for a total of 1500 mg). A triple immunosuppressive regimen based on calcineurin inhibitors (cyclosporine or tacrolimus), mycophenolate acid (mycophenolate mofetil or mycophenolate sodium), and oral methylprednisolone was used. During postoperative immunosuppressive therapy, the dosage of calcineurin inhibitors is adjusted according to the blood concentration.

Diagnostic criteria for tuberculosis

According to the WHO TB guidelines, detecting *Mycobacterium tuberculosis* through culture or histopathology is considered the gold standard for diagnosis. The absence of etiological or pathological diagnosis is defined by the following criteria: (1) Clinical and imaging findings consistent with tuberculosis characteristics; (2) Positive tuberculin skin test or interferon-gamma release assay (IGRA); (3) Positive PCR for Mycobacterium tuberculosis; (4) Exclusion of other infectious causes; and (5) Effective response to diagnostic anti-tuberculosis treatment. Tuberculosis diagnosis is confirmed upon meeting three of the aforementioned criteria [7–9].

Treatment of tuberculosis

The whole TB chemotherapy program was conducted according to local guidelines. The duration of medication depends on the patient's responsiveness to anti-tuberculosis drugs. The drug concentration of tacrolimus/cyclosporine is reviewed regularly and the immunosuppressive dose is adjusted accordingly.

Cure criteria

The criteria for discontinuation of drug therapy were the completion of the treatment course and the absence or resolution of tuberculosis-related imaging findings. Additionally, for extrapulmonary tuberculosis, discontinuation criteria included the absence of symptoms and negative cultures.

Follow-up

Following discharge, the patients underwent regular follow-up appointments in the outpatient department every 2 weeks during anti-tuberculosis therapy and subsequently, every 1 to 2 months thereafter. The contents of review and follow-up included blood routine, liver function, kidney function, electrolyte, blood glucose measurement, immunosuppressive drug concentration, urinary sediment, etc. Relevant adverse events such as drug-induced liver damage, acute kidney injury (AKI), acute kidney rejection (AR), graft survival and recipient survival were recorded during anti-tuberculosis therapy. The patients in the tuberculosis group were followed up for 2 years from the start of anti-tuberculosis therapy.

Statistical methods

SPSS 26.0 software was used for statistical analysis. The measurement data conforming to normal distribution is expressed by mean ± standard deviation, and the measurement data of non-normal distribution is expressed by median (interquartile distance). Qualitative data were expressed as frequency (percentage) and Chi-square test was used to analyze the difference between groups. The risk factors screened in the process of univariate analysis were used as explanatory variables, and multivariate logistic regression was used to evaluate the odds ratio (OR) and 95% Confidence Interval (CI) of explanatory variables against target results, P value < 0.05 was considered statistically significant. Kaplan–Meier curve was

used to estimate graft and recipient survival, and log-rank test was used to compare differences between groups.

Results

Clinical results

A total of 31 cases out of 2185 DD donor kidney transplantations were diagnosed with tuberculosis following transplantation, and the total incidence of tuberculosis was 1.4%. All patients in tuberculosis group and control group did not receive isoniazid prophylactic therapy. Both groups were followed up for 2 years from the time the TB group received anti-TB therapy.

Baseline characteristics

The demographic characteristics and basic clinical data of the tuberculosis group and the control group are shown in Table 1. The tuberculosis group comprised 25 males (80.6%). The most commonly used immunosuppressant regimen after transplantation was Tacrolimus (Tac) + Mycophenolate + Methylprednisolone (80.6%). The median duration of onset was 10.8 months (IQR, 5–24), and the median duration of anti-tuberculosis treatment was 8 months (IQR, 7–10). The control group included 21 males (67.7%). The most commonly used immunosuppressive regimen after transplantation was Tacrolimus + Mycophenolate + Methylprednisolone (96.8%).The analysis found that the median age of the tuberculosis group was 42 years old (IQR, 35–48) compared with 33 years old (IQR, 27–46) in the control group ($P < 0.05$); The prevalence of diabetes in tuberculosis group was higher than that in control group and the difference was statistically significant (35.5% vs.6.5%, $P < 0.05$); The prevalence of hepatitis in tuberculosis group was higher than that in control group, and the difference was statistically significant (29.0% vs.6.5%, $P < 0.05$)

Table 1 Clinical characteristics of tuberculosis patients and matched controls from the same donor

Variables	Tuberculosis (n = 31)	Control (n = 31)	P value
Age, year, median (IQR)	42(35–48)	33(27–46]	0.042
Male, *n* (%)	25 (80.6)	21(67.7)	0.246
BMI, kg/m^2, median (IQR)	21.8(19.96–23.28)	21.2(19.40–24.10)	0.446
Hemodialysis, *n* (%)	25 (80.6)	23(74.2)	0.544
Peritoneal dialysis, *n* (%)	4 (12.9)	5(16.1)	0.718
Non-dialysis, *n*(%)	2 (6.5)	3(9.7)	0.641
Dialysis time, month, median (IQR)	12(7–24)	10(4–23)	0.799
Primary transplantation, *n*(%)	30 (96.8)	31(100)	0.313
Secondary transplantation, *n* (%)	1 (3.2)	0	0.313
Cause of ESRD			
Chronic glomerulonephritis, *n*(%)	22 (71.0)	25(80.6)	0.313
Diabetic nephropathy, *n*(%)	5 (16.1)	3(9.7)	0.449
Hypertensive nephropathy, *n*(%)	3 (9.7)	3(9.7)	1
IgA nephropathy, *n*(%)	1 (3.2)	0	0.313
Immunosuppressive regimen			
Tacrolimus + mycophenolate + methylprednisolone, *n*(%)	25 (80.6)	30(96.8)	0.108
Cyclosporine + mycophenolate + methylprednisolone, *n*(%)	6 (19.4)	1(3.2)	0.108
Onset time post-transplant, month, median (IQR)	11(5–24)		
Comorbidity and complication			
Hypertension., *n*(%)	30 (96.8)	29(93.5)	0.554
Diabetes., *n*(%)	11(35.5)	2(6.5)	0.013
Hepatitis B and C, *n*(%)	9 (29.0)	2(6.5)	0.046
BK infection, *n*(%)	6 (19.4)	0	0.108
CMV infection, *n*(%)	7 (22.6)	1(3.2)	0.058
Induction immunosuppression			
ATG, *n*(%)	18 (58.0)	17(54.9)	0.798
Basiliximab, *n*(%)	7 (22.6)	9(29.0)	0.562
No-induction, *n*(%)	6 (19.4)	5(16.1)	0.74

Clinical characteristics of the tuberculosis group

Fever was the predominant symptom in the early stages of tuberculosis for 80.6% (25/31) of patients in this study, with temperatures ranging from 37.5 °C to 40.2 °C. High fever was common. 15 patients were accompanied by systemic symptoms such as fatigue and weight loss, and some patients had respiratory symptoms such as cough and sputum. Extrapulmonary tuberculosis was present in 3 of the 31 patients with TB. Specifically, these cases manifested as tuberculous abscesses located in the left thigh, right abdominal wall, and left leg, respectively. In the tuberculosis group, 22 patients were positive in gamma interferon release test, 12 patients were positive in body fluid acid-fast bacillus stain test, 4 patients were diagnosed by pathogen whole-genome sequencing (WGS), 3 patients were diagnosed by culture of abscesses fluid, and 1 patient was diagnosed as tuberculosis infection by puncture biopsy. All patients underwent high-resolution chest CT scans upon the onset of fever. 13 patients showed miliary nodules on CT, 6 patients showed tuberculous cavity, 9 patients showed hilar or mediastinal lymph node enlargement, and 3 patients showed local effusion.

Treatment and prognosis of tuberculosis group

All 31 patients in the tuberculosis group received anti-tuberculosis therapy, and the specific drug regimen was shown in Table 2. The median treatment time was 10 months (IQR, 9–12). Sixteen patients (51.6%) received isoniazid + rifampicin/rifapentine + pyrazinamide + ethambutol regimen, six patients (19.4%) received isoniazid + rifampicin/rifapentine + pyrazinamide regimen, and eight patients (25.8%) received isoniazid + rifampicin/rifapentine + ethambutol + moxifloxacin regimen. One patient (3.2%) had isoniazid and rifampicin resistance genes and was treated with cycloserine + protionamide + linezolid + moxifloxacin regimen. Adverse reactions occurred during the treatment: drug induced liver injury in five cases (16.1%), acute kidney injury in six cases (19.4%), acute rejection in three cases (9.7%), graft loss in 3 cases (9.7%). Of these, 30 cases (96.8%) were cured after treatment and 1 case (3.2%) died.

Comparison of serum creatinine and glomerular filtration rate between tuberculosis group and control group

In this study, the serum creatinine values of the tuberculosis group were measured at 1 week, 1 month, 3 months, 6 months, and 12 months after receiving anti-tuberculosis therapy and the serum creatinine values were compared with those of the control group at corresponding time points. There were no significant differences in serum creatinine levels between the tuberculosis and control groups during the initial phase of anti-tuberculosis treatment. However, at the 3-month mark following anti-tuberculosis therapy, a notable increase in serum creatinine levels was observed in the tuberculosis group.

Serum creatinine (Fig. 2) of the experimental group and the control group before the start of anti-tuberculosis therapy (PD) and at 1 week, 1 month, 3 months, 6 months, and 12 months after anti-tuberculosis therapy. $^{*}P < 0.05$; $^{**}P < 0.01$.

Survival analysis comparison between tuberculosis group and control group

Graft and recipient survival were monitored in both groups for up to 2 years following the initiation of anti-tuberculosis treatment. In the tuberculosis group, one individual died and three individuals experienced loss

Table 2 Treatment and prognosis of tuberculosis patients

Treatment and outcomes ($n = 31$) case		Control
TB treatment strategy	***n*(%)**	***n*(%)**
HRZE	16 (51.6)	
HRZ	6 (19.4)	
HREMfx	8 (25.8)	
CsPtoMfxLzd	1 (3.2)	
Adverse drug reactions during treatment		
Drug-induced liver damage	5 (16.1)	
Complete cure	30 (96.8)	
Death	1 (3.2)	0
Graft loss	3 (9.7)	0
Acute rejection	3 (9.7)	0
Acute kidney injury	6 (19.4)	1(3.2)

H, Isoniazid; R, Rifampicin; Z, Pyrazinamide; E, Ethambutol; Mfx, Moxifloxacin; Cs, Cycloserine; Pto, Protionamide; Lzd, Linezolid

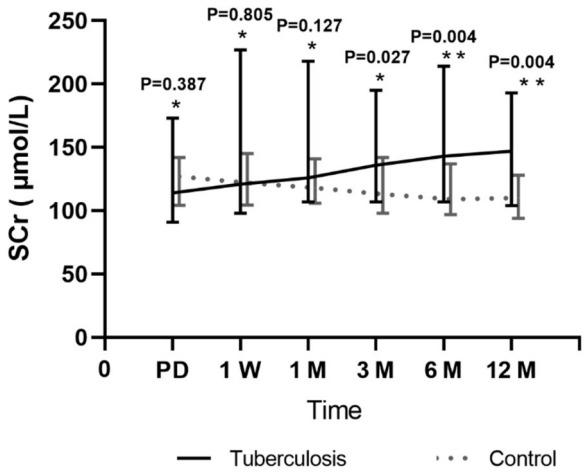

Fig. 2 Changes in creatinine and glomerular filtration rate between groups post-TB treatment

of work ability during the follow-up period. In contrast, no deaths or disabilities occurred in the control group. In the tuberculosis group, three cases of graft loss were observed. Kaplan–Meier curves were used to estimate graft and patient survival. The log-rank test compared survival between groups, as depicted in Fig. 3. Graft survival differed significantly between groups ($p=0.042$), while patient survival did not ($p=0.302$).

Risk factor analysis for tuberculosis using binary logistic regression

Univariate logistic regression analysis revealed age ($p=0.037$), diabetes mellitus ($p=0.012$), hepatitis ($p=0.032$), and CMV infection ($p=0.049$) as significant risk factors for tuberculosis ($p<0.05$). Multivariate logistic regression identified diabetes mellitus ($p=0.005$) and hepatitis ($p=0.027$) as independent risk factors for post-transplant tuberculosis. The results are presented in Table 3.

Discussion

In this study, we analyzed a total of 2185 DD donor kidney transplantations over the past 10 years, identifying 31 cases of TB infection with an incidence rate of 1.4%. A matched case–control analysis compared these cases to 31 non-TB controls from the same donor pool. While overall patient survival was similar between groups, TB patients experienced a significant decline in kidney function. Diabetes mellitus and hepatitis emerged as independent risk factors for post-transplant TB.

It has been reported that the incidence of tuberculosis after renal transplantation is 0.5–3.2% [10]. In Brazil, an area with a high incidence of TB, a retrospective study reported an incidence of 1.17% to 5% [11]. In our study, the incidence of tuberculosis was 1.4%. The potential infection mechanisms include the reactivation of latent *Mycobacterium tuberculosis* infection, direct transmission from the donor, and de novo acquisition of *Mycobacterium tuberculosis* [12]. In addition, immunosuppressive therapy renders recipients susceptible to *Mycobacterium tuberculosis*, facilitating rapid progression to miliary TB upon exposure [13]. Therefore, more detailed tuberculosis screening of donors before transplantation is conducive to reducing the incidence of TB after transplantation.

Most patients were infected with TB within 1 year after surgery, with a median onset time of 11 months after surgery (IQR, 5–25), which may be related to latent reactivation of mycobacterium tuberculosis. Therefore, the possibility of TB infection should not be ignored when a patient presents with a lung infection in the early post-transplant period. It has been documented that the risk of TB recurrence in latent TB patients is 5% per year for the first 5 to 7 years, then decreases to 0.1% per year [14].Therefore, in the early period after transplantation, more vigilance should be paid to the occurrence of tuberculosis.

At the beginning of anti-tuberculosis treatment, the comparison of creatinine changes between the two groups at different time points showed that there were significant differences in creatinine and glomerular filtration rate between the two groups at the 3rd, 6th and 12th month, and the greater the difference was with statistical significance as the treatment time extended. There were significant changes in creatinine curve and glomerular filtration rate curve between the two groups ($P=0.004$, $P=0.001$). A retrospective study of kidney transplant recipients with active tuberculosis revealed a graft loss rate of 14.7%. Additionally, tuberculosis treatment was associated with acute kidney injury and a failure of graft function returning to pre-infection baseline levels [15]. Costa et al. [7] showed that tuberculosis is significantly associated with the incidence of acute kidney injury (AKI) and the severity of AKI is an

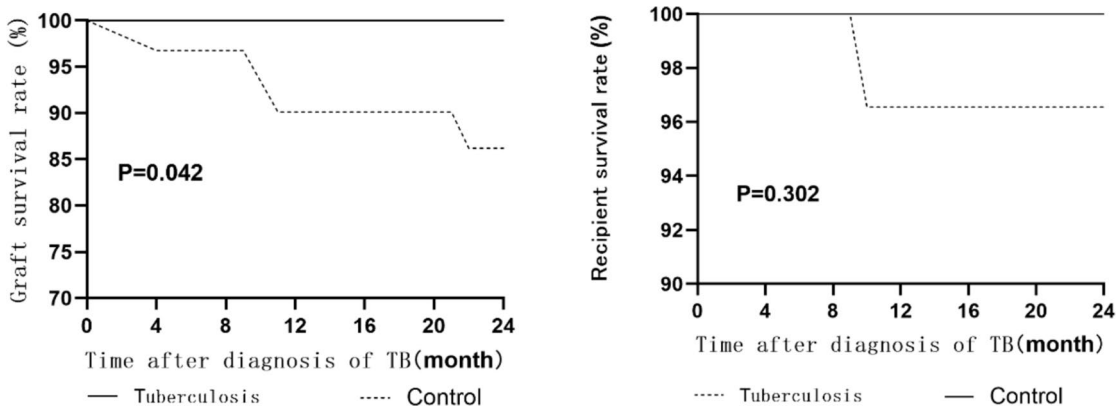

Fig. 3 Survival analysis of grafts and recipients after treatment

Table 3 Logistics analysis of risk factors for tuberculosis

Variables	Univariate			Multivariate		
	OR	95%CI	P	OR	95%CI	P
Age, year	1.052	1.003–1.103	0.037	1.018	0.964–1.076	0.517
Male, *n*(%)	0.504	0.157–1.618	0.25			
Dialysis						
Hemodialysis	1.449	0.436–4.814	0.545			
Peritoneal dialysis	0.77	0.186–3.190	0.719			
Non-dialysis	0.667	0.103–4.301	0.67			
Dialysis time	1.008	0.986–1.030	0.485			
PRA (+)	1.383	0.283–6.764	0.689			
PRA I(+)	3.214	0.316–32.741	0.324			
PRA II(+)	1.383	0.283–6.764	0.689			
Induction immunosuppression						
ATG	1.14	0.418–3.114	0.798			
Basiliximab	1.403	0.446–4.406	0.562			
No-induction	0.801	0.217–2.963	0.74			
Immunosuppressive regimen						
Tacrolimus + mycophenolate + methylprednisolone	1.714	0.146–20.097	0.668			
Cyclosporine + mycophenolate + methylprednisolone	7.2	0.016–1.232	0.76			
Hypertension	2.069	0.178–24.075	0.561			
Diabetes	7.975	1.593–39.927	0.012	11.028	2.032–59.854	0.005
Hepatitis B and C	5.932	1.163–30.254	0.032	7.186	1.251–41.264	0.027
History of BK virus infection	7.2	0.812–63.854	0.076			
History of CMV infection	8.75	1.006–76.097	0.049	9.214	0.931–91.177	0.058
History of DGF	2.127	0.637–1.611	0.23			

important factor in determining the prognosis of transplanted kidney function. The studies by Viana et al. [8] show that about 25% of patients will experience graft loss after anti-TB treatment and 20% of patients will stop taking the drug due to drug toxicity. Our study reported acute kidney injury, acute rejection, and graft loss in 6 (19.35%), 3 (9.68%), and 3 (9.68%) cases, respectively, underscoring the critical need for close renal function monitoring and delicate immunosuppressant management in this patient population.

Rifampicin, an anti-tuberculosis medication, is known to interact significantly with immunosuppressive agents. By inducing both P-glycoprotein (P-gp) and cytochrome P450 3A4 (CYP3A4), rifampicin can substantially reduce the levels of calcineurin inhibitors, thereby increasing the risk of graft rejection during anti-tuberculosis therapy and potentially compromising renal function [16]. To maintain therapeutic levels of calcineurin inhibitors during post-transplant anti-tuberculosis treatment, a threefold dose increase is often required [1]. Therefore, meticulous immunosuppressant management and close drug level monitoring are essential during TB treatment to prevent AKI, rejection and graft loss.

Previous studies have shown that the mortality rate of kidney transplant patients infected with tuberculosis is 14.3–31.9%, which is mainly related to the severity of tuberculosis and treatment complications [17]. Bodro et al.'s study of tuberculosis infection after transplantation also revealed a 17% mortality rate [18]. In this study, only one patient (3.2%) died following tuberculosis infection. Reviewing this case, we determined the cause of death to be respiratory failure secondary to severe pneumonia. Drug-induced hepatotoxicity developed after 1 week of treatment, as evidenced by elevated transaminase levels. Intermittent drug interruptions posed a risk of treatment failure and contributed to the fatal outcome. All 30 remaining patients with tuberculosis infection were successfully treated. The median treatment duration for the tuberculosis group was 8 months (IQR, 7–10). One of the 30 patients exhibited resistance to isoniazid and rifampicin. This patient underwent a 14-month treatment regimen with cycloserine, moxifloxacin, protionamide, and linezolid, resulting in a successful cure. The mortality rate in our center was lower than reported in some studies. This may be attributed to our vigilance on TB infection and early diagnosis facilitated by advanced technologies such as NGS and TB PCR testing.

Multivariate logistic regression analysis identified diabetes mellitus (OR 11.03, 95% CI 2.03–59.85, $p=0.005$) and hepatitis (OR 7.19, 95% CI 1.25–41.26, $p=0.027$) as independent risk factors for TB infection, consistent with previous literature [19, 20]. A meta-analysis of 13 observational studies revealed a two- to threefold increased risk of tuberculosis infection among individuals with diabetes[21]. Diabetes is a noncommunicable disease that can impair host immunity and lead to increased susceptibility to various infectious diseases, including tuberculosis [22].Diabetes impairs the innate response of TB patients to the initial TB infection, leading to delayed adaptive immune response, which is a key mechanism by which hyperglycemia contributes to TB susceptibility [23]. Strict glycemic control is crucial for preventing tuberculosis in transplant recipients. Previous studies have shown that compared with non-diabetic patients, diabetic patients may have lower interferon gamma release, and tuberculosis spot test has lower sensitivity in diabetic patients, which leads to delayed diagnosis of tuberculosis infection [24, 25]. Diabetes also has an important impact on the effectiveness of TB treatment [26]. TB patients with diabetes are also at increased risk for delayed sputum culture conversion, treatment failure, recurrence, and mortality [27].

Of the 9512 TB cases reported in New York City from 2000 to 2010, 350 (3.7%) TB cases were co-infected with chronic hepatitis, compared to 1.2% in the general population, demonstrating the close relationship between the two infectious diseases [28]. A large number of studies have shown that TB patients with hepatitis are more likely to develop liver dysfunction after receiving anti-TB therapy than TB patients without hepatitis [29, 30]. Given the increased risk of liver toxicity associated with anti-tuberculosis drugs, patients with hepatitis require particularly close monitoring of liver function. Careful drug selection, dose adjustment, and timely intervention, including drug cessation and liver protective measures, are essential to prevent adverse outcomes [31].

This study has several limitations. Information regarding latent tuberculosis infection was not included in this article as systematic screening was not performed for the studied patients. The relatively small sample size restricted the statistical power of our analyses. Moreover, the 2-year follow-up period may have underestimated long-term outcomes. Future research should incorporate immunosuppressive drug levels to elucidate their role on balancing TB treatment and graft survival.

In conclusion, our study highlights the significant impact of tuberculosis (TB) on kidney transplant recipients, emphasizing the importance of early detection and comprehensive management. While standard anti-TB treatment is effective, the risk of kidney dysfunction necessitates close monitoring and tailored immunosuppression strategies. Identifying diabetes mellitus and hepatitis as independent risk factors underscores the need for targeted preventive interventions in high-risk populations. Further research with larger sample sizes and extended follow-up periods is warranted to refine our understanding of post-transplant TB and optimize patient outcomes.

Author contributions

HZ drafted the manuscript. MZ collected and analyzed data.LT, SH, LP, and XX revised the manuscript. GL designed the outline of the manuscript and revised the manuscript. All authors have contributed to editing of manuscript. Hedong Zhang and Mingda Zhong contribute equally to this work and share first authorship.

Funding

This work is supported by Hunan Provincial Natural Science Foundation of China (2023JJ40872, 2023JJ30755), National Science Foundation of China (82370760).

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Second Xiangya Hospital, Central South University, in accordance with the requirements of the Declaration of Helsinki.

Competing interests

The authors declare no competing interests.

Received: 29 August 2024 Accepted: 2 March 2025
Published online: 14 March 2025

References

1. Makanda-Charambira PD, et al. TB in paediatric kidney transplant recipients—a single-centre experience. Pediatr Transpl. 2022;26(1): e14141.
2. Alene KA, et al. Spatiotemporal patterns of tuberculosis in Hunan province, China. Int J Environ Res Public Health. 2021;18(13):6778.
3. Ding C, et al. Epidemic trends of tuberculosis in China from 1990 to 2017: Evidence from the Global Burden of Disease Study. Infect Drug Resist. 2020;13:1663–72.
4. MacNeil A, et al. Global epidemiology of tuberculosis and progress toward meeting global targets—worldwide, 2018. MMWR Morb Mortal Wkly Rep. 2020;69(11):281–5.
5. Ai JW, et al. Updates on the risk factors for latent tuberculosis reactivation and their managements. Emerg Microb Infect. 2016;5(2): e10.
6. Singh N, Paterson DL. *Mycobacterium tuberculosis* infection in solid-organ transplant recipients: impact and implications for management. Clin Infect Dis. 1998;27(5):1266–77.
7. Costa SD, et al. Tuberculosis after kidney transplantation is associated with significantly impaired allograft function. Transpl Infect Dis. 2017;19(5): e12750.
8. Viana LA, et al. Influence of epidemiology, immunosuppressive regimens, clinical presentation, and treatment on kidney transplant outcomes of patients diagnosed with tuberculosis: a retrospective cohort analysis. Am J Transplant. 2019;19(5):1421–31.

9. Gras J, et al. Clinical characteristics, risk factors, and outcome of tuberculosis in kidney transplant recipients: a multicentric case-control study in a low-endemic area. Transpl Infect Dis. 2018;20(5): e12943.
10. Boubaker K, et al. *Mycobacterium tuberculosis* infection following kidney transplantation. Biomed Res Int. 2013;2013: 347103.
11. Meinerz G, et al. Epidemiology of tuberculosis after kidney transplantation in a developing country. Transpl Infect Dis. 2016;18(2):176–82.
12. Benito N, et al. Clinical features and outcomes of tuberculosis in transplant recipients as compared with the general population: a retrospective matched cohort study. Clin Microbiol Infect. 2015;21(7):651–8.
13. Tonelli M, et al. Systematic review: kidney transplantation compared with dialysis in clinically relevant outcomes. Am J Transplant. 2011;11(10):2093–109.
14. Bumbacea D, et al. The risk of tuberculosis in transplant candidates and recipients: a TBNET consensus statement. Eur Respir J. 2012;40(4):990–1013.
15. Marques ID, et al. Clinical features and outcomes of tuberculosis in kidney transplant recipients in Brazil: a report of the last decade. Clin Transplant. 2013;27(2):E169–76.
16. Munoz L, Santin M. Prevention and management of tuberculosis in transplant recipients: from guidelines to clinical practice. Transplantation. 2016;100(9):1840–52.
17. Higuita LM, et al. Tuberculosis in renal transplant patients: the experience of a single center in Medellin-Colombia, 2005–2013. J Bras Nefrol. 2014;36(4):512–8.
18. Bodro M, et al. Clinical features and outcomes of tuberculosis in solid organ transplant recipients. Transpl Proc. 2012;44(9):2686–9.
19. Subramanian AK, Theodoropoulos NM. Infectious diseases community of practice of the American society of, *Mycobacterium tuberculosis* infections in solid organ transplantation: guidelines from the infectious diseases community of practice of the American society of transplantation. Clin Transplant. 2019;33(9):13513.
20. Thitisuriyarax S, et al. Risk factors and clinical outcomes of tuberculosis among kidney transplant recipients in high endemic country. Transpl Infect Dis. 2021;23(3): e13566.
21. Jeon CY, Murray MB. Diabetes mellitus increases the risk of active tuberculosis: a systematic review of 13 observational studies. PLoS Med. 2008;5(7): e152.
22. Martinez N, Kornfeld H. Diabetes and immunity to tuberculosis. Eur J Immunol. 2014;44(3):617–26.
23. Podell BK, et al. Non-diabetic hyperglycemia exacerbates disease severity in *Mycobacterium tuberculosis* infected guinea pigs. PLoS ONE. 2012;7(10): e46824.
24. Kobashi Y, et al. Clinical evaluation of QuantiFERON TB-2G test for immunocompromised patients. Eur Respir J. 2007;30(5):945–50.
25. Faurholt-Jepsen D, et al. Diabetes is associated with lower tuberculosis antigen-specific interferon gamma release in Tanzanian tuberculosis patients and non-tuberculosis controls. Scand J Infect Dis. 2014;46(5):384–91.
26. Faurholt-Jepsen D, et al. The role of diabetes co-morbidity for tuberculosis treatment outcomes: a prospective cohort study from Mwanza. Tanzania BMC Infect Dis. 2012;12:165.
27. Faurholt-Jepsen D, et al. Diabetes is a strong predictor of mortality during tuberculosis treatment: a prospective cohort study among tuberculosis patients from Mwanza. Tanzania Trop Med Int Health. 2013;18(7):822–9.
28. Chitnis AS, et al. Epidemiology and prevention of tuberculosis and chronic Hepatitis B virus infection in the United states. J Immigr Minor Health. 2021;23(6):1267–79.
29. Chien JY, et al. Hepatitis C virus infection increases hepatitis risk during anti-tuberculosis treatment. Int J Tuberc Lung Dis. 2010;14(5):616–21.
30. Sirinak C, et al. Viral hepatitis and HIV-associated tuberculosis: risk factors and TB treatment outcomes in Thailand. BMC Public Health. 2008;8:245.
31. Bushnell G, et al. Characteristics and TB treatment outcomes in TB patients with viral hepatitis, New York City, 2000–2010. Epidemiol Infect. 2015;143(9):1972–81.

Publisher's Note